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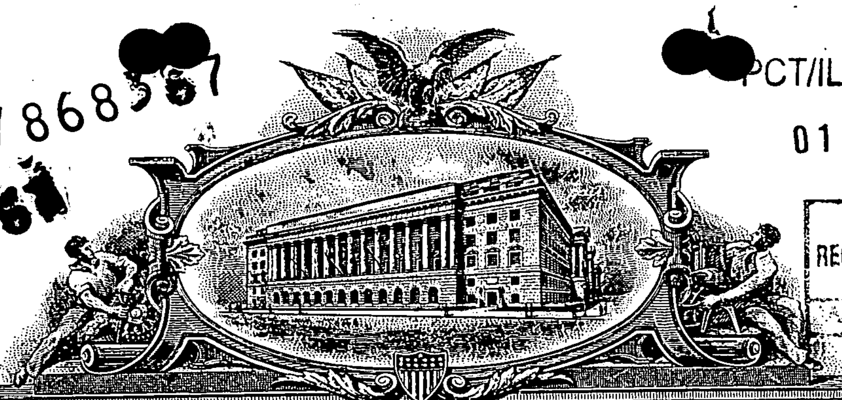

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TITLE OF THE INVENTION (280 characters max)

METAL-AIR BATTERY POWER SUPPLY

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WP-2749.1

METAL-AIR BATTERY POWER SUPPLY

SPECIFICATION

Field of the Invention

The present invention relates to disposable battery packs containing metal-air batteries. In particular, the present invention relates to a novel battery pack construction for prismatic, metal-air battery cells.

Background of the Invention

The present invention relates to disposable or semi-permanent battery packs containing a plurality of metal-air battery cells, or more particularly, metal-air battery packs for portable electronic devices.

Most high-drain portable electronic devices are powered by secondary – otherwise known as rechargeable – batteries. Examples of such high-drain devices are cellular telephones, notebook computers, camcorders, and cordless hand-tools. The reason primary batteries are unattractive in high-drain applications is that the longevity of typical primary – otherwise known as disposable batteries – is low when compared to its cost and weight, making the use of primary batteries too expensive for most consumers. For example, alkaline batteries can only supply a cellular telephone with about as much energy as a single charge of a nickel-metal-hydride battery, making the cost/energy of alkaline batteries very high.

New battery technologies have emerged that have the ability to offer sufficient energy and power to power high-drain devices at a sufficiently low cost. One such technology is metal-air batteries. The cathode of a metal-air battery is

oxygen – which can be supplied from the ambient air – thereby eliminating the need for the battery to house two electrodes. Housing only one electrode also significantly increases the battery's energy capacity per given volume. Unfortunately, this intrinsic benefit is attended by other intrinsic problems that must be addressed before metal-air batteries can become a commercially feasible alternative.

Although having a high energy density, metal-air batteries are moderately low on power. In order for metal-air batteries to provide high power, large amounts of oxygen must be supplied. However, portable electronic devices do not typically have a large surface area for air access. This creates some obvious design problems for hand-held consumer devices requiring high power but providing little surface area.

An additional problem with metal-air batteries is that they tend to desiccate in low humidity environments. Since oxygen must enter the battery through air holes on the battery, water vapor can exit the battery through the same air holes. As such, metal-air batteries are susceptible to desiccation, potentially destroying their ability to function or substantially reducing their useful life.

To increase the life of a metal-air battery, the diffusion of moisture out of the battery should be restricted when the electronic device requires little or no oxygen. This can be accomplished by blocking the air holes to reduce the rate that moisture diffuses through the air holes. However, completely blocking the air holes for extended periods of time may deprive the battery of oxygen, making the battery behave as if all its energy has been depleted. The battery may behave as if it was dead even after it is exposed to oxygen. It may take several minutes of exposure before the battery can generate sufficient quantities of current.

Leakage of water between or onto metal-air battery cells can cause the battery cells to short. Water from a multitude of sources can potentially enter the

battery pack and contact the metal-air battery cells, resulting in an electrical short. These water sources include sweat from the person handling the device, moisture from the user speaking near or into the device, or from water spilled on the device.

Finally, portable electronic devices place constraints on the weight and size of the battery. The battery must be sized to cost effectively deliver the required power while also conforming to the multitude of shapes found in cellular telephones, notebook computers, camcorders, and cordless hand-tools.

Summary of the Invention

It is an object of the present invention to provide a novel battery pack construction, with other related features, for housing a plurality of prismatic metal-air battery cells to power portable electrical devices, e.g. cellular phones. A battery pack is well suited to replace or supplement existing secondary power supplies.

Typically metal-air battery cells include a casing wall having one or more holes to permit the diffusion of oxygen from ambient air. Metal-air batteries generate power through an electrochemical reaction. To create power, oxygen reduction catalysts in the air cathode convert oxygen to hydroxyl ions. The hydroxyl ions then migrate to the anode causing the anode metal to oxidize. The anode liberates the electrons, which are then pumped through the load to offset a deficit caused by the oxygen reduction in the cathode. A preferable metal for the anode in these types of battery cells is zinc.

In order for metal-air batteries to provide high power, large amounts of oxygen must diffuse through the outer casing wall of the metal-air battery cell. In some cases, up to 0.0032 cc/sec/cm^2 may be required. This creates some obvious design problems for hand-held consumer electronic devices. Small portable

electronic devices do not typically provide large surface areas where oxygen can enter.

To provide sufficient air access for the metal-air batteries, the present invention provides has passive and active elements for air delivery. In one aspect of the invention, the casing of the battery has air access holes to ensure that the batteries have a sufficient supply of oxygen. Alternatively, an air deflector is added to the battery pack that deflects air into the battery pack when the electronic device is in use. In an additional aspect of the invention, a fan or other active airflow element is included in the battery pack to increase the flow of air to the metal-air batteries.

To reduce the rate at which the metal-air batteries desiccate the present invention restricts the diffusion of moisture out of the batteries when the electronic device demands little or no power. The battery pack has shutters, or a different type of blocking structure, that limits the desiccation of the batteries during low power demands by reducing the rate at which moisture can exit the battery pack.

To further control the supply of oxygen and the desiccation of the batteries, blocking elements, which can also electronically connect the batteries, are placed over the air holes of the batteries during low power demand. Although the blocking elements restrict the diffusion of oxygen through the air holes of the batteries, the blocking elements do not completely deprived the battery cells of oxygen.

To reduce the cost of powering an electronic device with a metal-air battery pack, many of the embodiments incorporate parts that can be reused several times. In most metal-air battery packs, the batteries are the only parts of the pack that need replacing. The electrical components, the desiccation prevention enhancements and the air enhancement features of many of the

embodiments described below can be reused several times without effecting the performance of the battery pack. In most embodiments, the user can partly dissemble or open the battery pack and replace the expended batteries with new batteries.

To prevent the entry of water into the battery pack and the accidental shorting of the metal-air batteries, air access holes on the battery pack casing are sized and/or positioned to hinder the entry of water, thereby preventing water from coming in contact with the metal-air batteries. Besides controlling the flow of oxygen to the battery pack, the shuttering elements and the expanding and collapsing elements of the battery pack also limit the entry of water into the battery pack. In an additional aspect of the invention, the battery pack casing is constructed of a hydrophobic material with small air holes. The air holes are sized so that water, when in contact with the outer surfaces of the casing, will likely bead up and be prevented from penetrating the casing.

Another issue with metal-air batteries is the limited space allowed for batteries in standard high current portable electronic devices. The present invention uses prismatic metal-air battery cells shaped to minimize wasted space, thereby having a high packing density and creating a compact battery pack design. The invention also has a battery pack that expands and contracts. Expanding the battery pack casing not only provides the battery cells with an increased supply of oxygen, but it also provides a larger and more comfortable area to which a user can hold the electronic device. Collapsing the casing during nonuse provides a more compact and portable design.

Finally, to prevent a battery pack from being accidentally recharged, the circuitry of the present invention is designed to prevent or limit the exposure of the batteries to a reverse current that may harm them. The invention also has physical blocking structures intended to prevent the user from physically

connecting the battery pack to a recharging device. Additionally, the circuitry can connect the batteries to an auxiliary supplemental power supply when the supplied voltage drops below a set value.

While the invention will now be described in connection with certain preferred embodiments and examples and in reference to the appended figures, the described embodiments are not intended to limit the invention to these particular embodiments. On the contrary, it is intended to cover all alternatives, modifications, and equivalents as may be included within the scope of the invention. Thus, the following description and examples of the preferred embodiments of the invention are only intended to illustrate the practice of the present invention. The particular embodiments are shown by way of example and for purposes of illustrative discussion of the preferred embodiments of the present invention. The particular embodiments are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects of the invention. In this regard, no attempt is made to show structural details of the invention in more detail than is necessary for a fundamental understanding of the invention. The description, taken with the drawings, make it apparent to those skilled in the art how the several forms of the invention may be embodied in practice.

Brief Description of the Drawings

Fig. 1 shows a perspective view of a prismatic metal-air battery cell.

Fig. 2A shows a cross-section representation of a clamshell type of casing in a first, compact or closed, configuration according to an embodiment of the invention.

Fig. 2B shows a cross-section representation of the embodiment of Fig. 2A in a second, expanded or open, configuration.

Fig. 2C shows another cross-section representation of the embodiment of Fig. 2A in a second, expanded or open, configuration.

Fig. 2D shows a partial cross-section representation of a clamshell type of casing in a first, compact or closed, configuration. The recesses of the casing hold the cells in place

Fig. 3A shows a cross-section representation of a prismatic metal-air battery cell adjacent to an air permeable blocking element.

Fig. 3B shows a cross-section representation of a prismatic metal-air battery cell adjacent to a blocking element with minor protrusions on one of its major surfaces.

Fig. 3C shows a perspective view of a prismatic metal-air battery cell adjacent to a blocking element containing air channels.

Fig. 3D shows a cross-section representation of the embodiment of Fig. 3C.

Fig. 3E shows a cross-section representation of two prismatic metal air-battery cells and a blocking element with an embedded conductive spring. The conductive spring contacts the two battery cells.

Fig. 3F shows a cross-section representation of the embodiment of Fig. 3E. The two battery cells bend the conductive spring.

Fig. 3G is perspective view of the blocking element of the embodiment of Figs. 3E and 3F.

Fig 4A shows a cross-section representation of a clamshell type of casing, similar to the embodiment of Figs. 2A and 2B, in a first, compact or closed, configuration with the battery cells arranged so that the air access holes of every battery cell face the base of the battery casing.

Fig 4B shows a cross-section representation of the embodiment of Fig. 4A in a second, expanded or open, configuration.

Fig. 5A shows a cross-section representation of clamshell type casing, similar to the embodiment of Figs. 2A and 2B, in a first, compact or closed, configuration with flexible strips attaching the battery cells to the cover and the base of the battery casing.

Fig. 5B shows a cross-section representation of the embodiment of Fig. 5A in a second, expanded or open, configuration.

Fig. 6A shows a cross-section representation of a clamshell type casing, similar to the embodiment of Figs. 5A and 5B, in a second, expanded or open, configuration. A plurality of flexible strips attaches the battery cells to the cover of the battery casing and a plurality of flexible strips attaches the battery cells to the base of the battery casing.

Fig. 6B shows a partial cross-section representation of an embodiment similar to the embodiment of Fig. 6A. Electrically conductive contacts are embedded in the strips that attach the battery cells to the casing.

Fig. 6C shows a cross-section representation of the strip of the embodiment of Fig. 6B.

Fig. 6D shows a perspective view of the strip of the embodiment of Fig. 6B

Fig. 7 shows a partial cross-section representation of a clamshell type casing, similar to the embodiment of Figs. 5A and 5B, in a first, compact or closed, configuration. A plurality of flexible strips passes through apertures in the base and cover of the battery casing and attaches to the outer surfaces of the base and cover.

Fig. 8A shows a cross-section representation of a clamshell type casing, similar to the embodiment of Figs. 2A and 2B, in a first, compact or closed, configuration. The casing has a plurality of springs and a latch.

Fig. 8B shows a cross-section representation of the embodiment of Fig. 8A in a second, expanded or open, configuration

Fig. 8C shows a partial cross-section representation of the embodiment of Figs. 8A and 8B, with the latching mechanism shown in greater detail.

Fig. 9 shows a partial cross-section representation of a clamshell type casing, similar to the embodiment of Figs. 8A and 8B, in a first, compact or closed, configuration. The casing transforms through the use of a détente spring mechanism.

Fig. 10A shows a cross-section representation of a casing enclosing a 2x3 array of battery cells where the air holes of the battery cells face an inner plenum.

Fig. 10B shows a different cross-section representation of the embodiment of Fig. 10A.

Fig. 10C shows the electrical schematics of the embodiment of Fig. 10A.

Fig. 11A shows an expanded cross-section representation of a clamshell type casing where the casing traps a volume of air.

Fig. 11B shows a perspective view of the embodiment of Fig. 11A in a first, compact or closed, configuration.

Fig. 11C shows a perspective view of the embodiment of Fig. 11A in a second, expanded or open, configuration.

Fig. 11D shows an expanded perspective view of the embodiment of Fig. 11A.

Fig. 11E shows an expanded perspective view of an alternative shuttering assembly.

Figs. 11F and 11G shows two cross-section representations of the shuttering assembly of Fig. 11E

Fig. 12A shows a perspective view of a casing having grooves and air holes in the recesses of the grooves.

Fig. 12B shows a cross-section representation of the casing of Fig. 12A when placed against a flat surface.

Fig. 13 shows a cross-section representation of a cellular phone with an attached battery casing having an air deflector.

Fig. 14A shows a cross-section representation of a casing having a fan to propel air over the air holes of the battery cells

Fig. 14B shows a perspective view of the embodiment of Fig. 14A.

Fig. 14C shows a perspective view of a filler piece that surrounds a plurality of battery cells.

Fig. 15A shows a cross-section representation of a casing in its first, compact or closed, configuration, housing a plurality of battery cells connected to each other by a plurality of springs.

Fig. 15B shows a perspective view of the inner sleeve of the embodiment of Fig. 15A.

Fig. 15C shows a perspective view of the outer sleeve of the embodiment of Fig. 15A.

Fig. 15D shows a cross-section representation of the inner and outer sleeves of the embodiment of Fig. 15A.

Fig. 15E shows a cross-section representation of the embodiment of Fig. 15A in a second, expanded or open, configuration.

Figs. 15F – 15I show partial cross-section representations of four alternatives of the springs of the embodiment of Fig. 15A.

Fig. 16A shows a cross-section representation of a clamshell type casing in a second, expanded or open, configuration.

Fig. 16B shows a cross-section representation of the embodiment of Fig. 16A in its first, compact or closed, configuration.

Fig. 16C shows a cross-section representation of an embodiment similar to the embodiment of Fig. 16A in a first, compact or closed, configuration.

Fig. 16D shows a cross-section representation of an embodiment similar to the embodiment of Fig. 16A in a first, compact or closed, configuration.

Fig. 17A shows a cross-section representation of a clamshell type casing in a first, compact or closed, configuration. A hinge connects the base and cover of the casing.

Fig. 17B shows a cross-section representation of the embodiment of Fig. 17A in a second, expanded or open, configuration.

Fig. 18A shows a cross-section representation of a clamshell type casing where the cells are attached to the base or cover.

Fig. 18B shows a cross-section representation of the embodiment of Fig. 18A in a second, expanded or open, configuration.

Fig. 19A shows a cross-section representation of a casing having apertures on the sides of the cover and a blocking element attached by a hinge.

Fig. 19B shows an activation bar of the embodiment of Fig. 19A.

Fig. 19C shows a partial cross-section representation of the embodiment of Fig. 19A.

Fig. 19D shows another cross-section representation of the embodiment of Fig. 19A.

Fig. 19E shows a cross-section representation of an embodiment similar to the embodiment of Fig. 19A, having a flexible blocking element.

Fig. 20 shows a cross-section representation of an embodiment where the air holes of the battery cells face the casing of the battery cells.

Fig. 21A shows a cross-section representation of a cellular phone with an attached battery having a switching mechanism.

Fig. 21B shows a partial cross-section representation of the sliding switch mechanism of the embodiment of Fig. 21A

Fig. 21C shows a different partial cross-section representation of the sliding switch mechanism of the embodiment of Fig. 21A

Fig. 22 shows a cross-section representation of cellular phone with an attached rechargeable battery and an attached battery pack.

Fig. 23A shows a schematic diagram of a current limiting circuit according to an embodiment of the invention.

Fig. 23C shows a schematic diagram of a voltage varying circuit

Fig. 23D shows a schematic diagram of the voltage varying circuit of Fig. 23C but with the switches in a different position.

Fig. 24A shows a cross-section of a single battery cell holder having electrical contacts.

Fig. 24B shows a different cross-section of the embodiment of Fig. 24A.

Fig. 24C shows a partial cross-section of the embodiment of Fig. 24A.

Fig. 24D shows a partial cross-section of an alternative embodiment similar to the embodiment of Fig. 24A.

Fig .24 E shows a perspective view of the embodiment of Fig. 24A.

Fig. 25A shows a cross-section of an alternative embodiment of a single battery cell holder having electrical contacts.

Fig. 25B shows a different cross-section of the embodiment of Fig. 25A.

Fig. 25C shows a cross-section of an alternative embodiment similar to the embodiment of Fig. 25A.

Detailed Description of the Illustrated Embodiments

Referring now to Fig. 1, a metal-air battery cell 10 has a plurality of air holes 11 on its first major surface 12. The cell 10 also has a second major surface 13 that lies opposite the first major surface 12. In certain metal-air battery cells 10, the first major surfaces 12 are electrically connected to the cathode (not shown) of the cells 10 and the second major surfaces 12 to the anode (not shown) of the cells 10, making them electrode terminals. In plastic cells, separate terminals may be attached to the body of the cells or alternatively the cells may be coated with a conductor.

Both air and moisture can diffuse across the first major surface 12 via the air holes 11. An air cathode (not shown) contained inside the casing of the cell 10 requires oxygen for the cell 10 to generate current. Oxygen from the atmosphere diffuses through the air holes 11 and into the air cathode (not shown). Oxygen is consumed in the cell 10 by an electrolytic reaction to generate electric power. Moisture also diffuses from inside the cell 10 to the outside of the cell 10, causing the cell 10 to desiccate, which can shorten its useful life.

The first major surface 12 can be made of a porous plastic or semi-permeable membrane, thereby eliminating or reducing the number or size of the air holes 11. Although the following descriptions make limited mention of the use of a porous plastic or a semi-permeable membrane, the use of these materials can also be incorporated in the cells 10 without modifying the described embodiments.

Ingress of the necessary oxygen for discharge is driven by Fick's Law. The difference in the partial pressure of oxygen across the first major surface 12 of the cell 10 forces oxygen to diffuse through the air holes 11 and into the air cathodes (not shown). The rate at which oxygen diffuses through the air holes 11

is determined, in part, by the gradient of the partial pressure of oxygen across the first major surface 12. To obtain desired voltages, multiple cells 10 can be connected together. Practical considerations can demand that these cells 10 be packaged in a container.

However, if the air immediately outside the first major surface 12 is not continuously replenished with oxygen, the rate at which oxygen diffuses through the air holes 11 will decrease. Assuming the cells 10 are encased in an enclosure, oxygen must diffuse from outside the casing to the air holes 11. Thus oxygen, at equilibrium, must diffuse through a longer path, from the air holes 11 to the outside, resulting in a lower gradient which drives the diffusion process at a slower rate. Replenishing the air above the first major surface 12 with oxygen can be accomplished by circulating fresh, oxygen-rich, air from the atmosphere over the first major surface 12.

The egress of water vapor out of the cells 11 is largely governed by Knudsen's diffusion. When the partial pressured of water ("ppH_2O") on one side of the first major surface 12 of the cell 10 is greater than the ppH_2O on the opposite side of the first major surface 12, moisture diffuses through the air holes 11 from the side with the greater ppH_2O to the side with the lower ppH_2O. Normally, the ppH_2O inside the cells 10 is greater than the ppH_2O outside the cells 10 because the zinc compound contained within the cell 10 is moist. Since the ppH_2O inside the cell 10 is usually greater than the ppH_2O immediately across the first major surface 12 of the cell 10, moisture normally diffuses out of the cell 10. The rate at which moisture diffuses through the air holes 11 is dependent on the gradient of the ppH_2O across the first major surface 12.

Referring now to Fig. 2A, a casing 20 is in its first, compact or closed, configuration. The casing 20 has two major casing elements, a base 21 and a cover 22. A plurality of flexible strips 23 connects a plurality of the cells 10 to

the cover 22. Each flexible strip 23 supports a respective cell 10. The cells 10 are positioned between the base 21 and the cover 22 so that all the cells 10 are substantially parallel and so that the first major surfaces 12 of the cells 10 face the cover 22.

Arranging the cells 10 so that they are substantially parallel with each other helps to reduce the space needed to house the cells 10. A primary benefit of using metal-air batteries is that they are capable of greater energy output, relative to their mass, than most other primary batteries. Minimizing the size of the battery is beneficial for portable devices. As described below, the configuration of Fig. 2A supports cells 10 in a tightly packed array that can be expanded during use when high power is required, as shown in Fig. 2B.

Every flexible strip 23 directly contacts or lies slightly above the first major surface 12 of a respective cell 10 when the casing 20 is in the first, compact or closed, configuration. When the casing 20 is in a compact or closed, configuration, the flexible strips 23 at least partially block the air holes 11 located on the first major surfaces 12 of the corresponding cells 10. For example, the flexible strip 23 located at position 27 at least partially blocks the air holes 11 of the cell 10 located at position 28.

When the casing 20 is in the first, compact or closed, configuration, a blocking element 25, which is attached to the cover 22, at least partially blocks the air holes 11 of the cell 10 located at position 26. Since the blocking element 25 performs a function similar to that of the flexible strips 23, the blocking element 25 may be made of the same material.

The flexible strips 23 and the blocking element 25 may be attached to the cover 22 and/or the cells 10 by an adhesive, or by a different attaching means. The flexible strips 23 and/or the blocking element 25 may be attached by glue or

by a self-adhesive applied to the surface(s) of the flexible strips 23 and/or the blocking element 25.

The blocking element 25 is attached to a relatively flat surface on the cover 22. This flat surface is substantially parallel to the cell 10 located at position 26 when the casing 20 is the first, compact or closed, configuration.

The base 21 is shaped so that the cells 10 are held in a regular array when the casing 20 is in the first, compact or closed, configuration. The base 21 may also support the cells 10 if the blocking element 25 and/or the flexible strips 23 are pressed against the first major surfaces 12 of the cells 10.

Referring now to Figs. 2B and 2C, the casing 20 is in its second, expanded or open, configuration. The flexible strips 23 and the blocking element 25 are separated from the first major surfaces 12 of the cells 10, thereby allowing more atmospheric air to enter, or more oxygen to diffuse, into the space between the flexible strips 23 and the cells 10. As explained above, the rate at which oxygen diffuses into the air cathodes (not shown) increases. Air can enter and exit the casing 20 through an opening 29 defined around the perimeter of the base 21 when the casing 20 is in the second, expanded or open, configuration. Air can also enter and exit the casing 20 through air holes (not shown) located on the cover 20. Note that the cell 10, located at position 24, remains attached to the base 21 and that the distance between each cell 10 has increased.

Increasing the distance between each cell 10 allows an increase in the rate at which oxygen diffuses into the cells 10 via the air holes 11 by allowing air to flow into the spaces between the cells 10. That is, increasing the space above the air holes 11 of the cells 10 can increase the rate at which air flows, or oxygen diffuses, into that space.

Manually rotating pivoting levers 30 transforms the casing 20 from the first, compact or closed, configuration to the second, expanded or open,

configuration, and vice-versa. The pivoting levers 30 pivot through approximately 80 degrees as the pivoting levers 30 guide the cover 22 from its first position to its second position, and vice-versa. A flat surface 34 on the base 21 prevents the pivoting levers 30 from over-rotating when the casing 20 is transformed to its second, expanded or open, configuration. The base 21 prevents the pivoting levers 30 from over-rotating when the casing 20 is transformed back to its first, compact or closed, configuration.

During the transformation of the casing 20, the cells 10 remain engaged in the recesses 31 formed on the base 21. With the exception of the cell 10 located at position 24, the shape of the recesses 31 and the flexibility of the flexible strips 25 prevent the cells 10 from completely leaving the recesses 31. Although not illustrated here, the cells 10 can also be attached to base 21 to prevent the cells 10 from completely leaving the recesses 31. The cells 10 pivot and the first major surfaces 12 of the cells separate from the respective flexible strips 23 or the respective blocking element 25.

The likelihood that the casing 20 may jam when it transforms from the first, compact or closed, configuration to the second, expanded or open, configuration, and vice versa, can be reduced by ensuring that the space between base 21 and the cover 22 is large enough to accommodate the cells 10 during the transformation. The location and design of the pivoting levers 30 determine the path the cover 22 will take when it separates from the base 21. Increasing the space surrounding the cells 10 may also reduce the likelihood that the casing 20 will jam.

The advantage of two selectable configurations, as shown in Figs. 2A and 2B, is that it allows desiccation to be minimized when the load is turned off and for air access to be increased when the load is turned on. As explained below, even when the load is turned off, a minimum amount of oxygen is required by the

cells 10 to prevent them from appearing temporarily dead when the load is suddenly turned on. Moreover, the load can vary depending on the operating mode of the load.

An electronic device's power requirements should be considered when designing a battery casing. A cellular phone, like most other electronic devices, has different power requirements depending, in part, on the function it is performing. Normally, a cellular phone requires more power when it is in "talk" or "standby" mode than when it is off.

When the phone is in "talk" mode, the phone requires a constant stream of current to operate properly. Permitting more air to diffuse through the air holes 11 of the cells 10 increases the potential for the cells 10 to generate higher levels of current. However, as explained above, increasing the rate at which oxygen diffuses through the air holes 11 may also increase the rate at which the cells 10 desiccate.

A typical analog cellular phone, when in "talk" mode, may draw between 600 – 700 mA of current, depending, in part, on the distance between the phone and the transmitting antenna and the surrounding atmospheric conditions. Likewise, a typical digital cellular phone may draw between 200 – 450 mA of current. For a typical metal-air battery pack, the cells 10 require oxygen at the combined rate of approximately 0.2 cc/sec to generate 600 mA of current and approximately 0.06 cc/sec of oxygen to generate 200 mA of current.

Using, as an example, the illustrative embodiment of Figs. 2A and 2B, the cells 10 are supplied with a sufficient supply of oxygen to power a cellular in "talk" mode when the casing 20 is in its second, expanded or open, configuration. Oxygen rich air can flow into the casing 20 through the opening 29 and through the other air holes (not shown) on the cover 21. Air movement is driven by

fluctuations in room air buoyancy effects of heat generated by the appliance and/or the battery, etc.

When the phone is in "standby" mode, the phone still requires a continuous stream of current. However, the phone requires less current in "standby" mode than when the phone is in "talk" mode. The casing 20 provides the cells 10 with a sufficient supply of oxygen to power a cellular phone in "standby" mode when the casing 20 is in its second, expanded or open, configuration.

However, since lower quantities of current are required to operate the phone in "standby" mode than in "talk" mode, the casing 20 may also be able to provide the cells 10 with a sufficient supply of oxygen when the casing 20 is in its first, compact or closed, configuration or some intermediate position (not shown). When the casing 20 is in its first, compact or closed, configuration, the flexible strips 23 and the blocking element 25 restrict, but do not completely cut off, the cell's 10 access to air.

When in "standby" mode, a typical analog cellular phone may draw between 15-30 mA of current, depending, in part, on the distance between the phone and the transmitting antenna and the surrounding atmospheric conditions. Likewise, a typical digital cellular phone may draw between 3 –15 mA of current. Using the same battery cell configuration used in the example above, the cells 10 require oxygen at the combined rate of approximately 36 cc/hr to generate 30mA of current and approximately 3.6 cc/hr to generate 3 mA of current.

Some loads may require sudden high bursts of electrical current, for example, a cellular phone when it rings. The cells 10 may have sufficient short term energy to enable the cells 10 to respond to such a load. However, it may be necessary to augment it in some way. One solution would be to incorporate, into

the design, a separate pulse battery that can provide the cellular phone with the burst of electrical current that is needed in those instances.

When the phone is off, the phone does not require any current from the cells 10. However, completely or substantially blocking the air holes 11 of the cells 10 may lead to an undesirable result. If the cells 10 are deprived of oxygen for extended periods of time, the cells 10 may not instantaneously provide the needed current even when the air holes 11 are uncovered and oxygen can diffuse into the cells 10. Minutes may pass before the cells 10 are able to provide enough current to power a phone. Permitting air to diffuse through the air holes 11 at a limited rate – even when the cellular phone is off – can reduce or eliminate the time delay before the cellular phone can be used again. For the battery cell configuration explained in the examples above, providing the cells 10 with oxygen at the rate of approximately 0.5 cc/hr prevents the cells 10 from entering this state of powerlessness.

Since the oxygen requirements are low, the air holes 11 of the cell 10 can be substantially blocked for extended periods without resulting in undesired consequences. The casing 20 can provide the cells 10 with restricted access to air, such as when the casing 20 is in the first, compact or closed, configuration. Providing this limited oxygen access is the subject of a discussion that will follow.

There are a number of factors to consider when choosing materials for the flexible strips 23 and/or the blocking element 25, including, but not limited to, the material's strength, rigidity, flexibility, durability, and permeability. When the casing 20 is in the first, compact or closed, configuration, the flexible strips 23 and the blocking element 25 should at least partially block the respective air holes 11 to reduce the rate at which the cell 10 desiccates. However, the flexible strips

23 and the blocking element 25 must also permit oxygen to diffuse into the air holes 11, albeit, at a limited rate.

As described above, it is preferable that the flexible strips 23 and the blocking element 25 allow oxygen to diffuse through the air holes 11 at some minimum rate. Various ways to effectuate this result for the embodiment of Figs. 2A - 2C and also for other embodiments that use flexible strips 23 and/or a blocking element 25 to block the air holes 11 of the cells 10 are described in the embodiments of Figs. 3A-G.

Although not illustrated here, a casing with rigid strips, instead of flexible strips, can also provide benefits similar to the benefits of the embodiment of Figs. 2A-C. The rigid strips could be attached to the respective cells 10 and to the cover 21. The rigid strips would have hinges at the locations on the rigid strip where the flexible strips 23 of Figs. 2A - 2C must bend. The use of rigid strips may even eliminate the need for pivoting levers as in the embodiment of Figs. 2A - 2C. The rigid strips can perform the same function as the pivoting levers.

Referring now to Fig. 2D, in an alternative embodiment, the flexible strips 23 of the embodiment of Figs. 2A – 2C have been eliminated. A casing 310 has two major casing elements, a base 311 and a cover 312. Both the base 311 and the cover 312 contain recesses 313 that are shaped so that the plurality of the cells 10 remains, at all times, engaged to the recesses 313 of the casing 310. Attached to the recesses of the casing are spring contacts 314. The spring contacts 314 connect the first and second major surfaces, 12 and 13, of the cells 10 to wiring (not shown) embedded in the casing 310. The wiring embedded in the casing 310 electrically connect the cells 10 together.

The casing 310 can be reused after the energy of the cells 10 have been depleted. The user can simply detach the cover 312 from the base 311 and replace

the expended cells 10. This feature can justify the user's decision to purchase a multi-featured but more expensive casing design.

Referring now to Fig. 3A, a blocking element 40 is made of an air permeable material that allows air to enter and exit through the sides 41 of the blocking element 40 and through other directly exposed areas. Air can enter through the sides 41 of the blocking element 40, diffuse through the blocking element 40, and eventually diffuse through the air holes 11 of the cell 10. The blocking element 40 can be made of a porous material that allows air to diffuse through blocking element 40 and through the air holes 11 at rate sufficient to power an electronic device. The dimensions of the blocking element 40 and area of the exposed surfaces of the blocking element 40 are factors that should be considered when choosing an appropriate material since these factors can affect the rate at which the cell 10 is supplied with oxygen. Some examples of material that may be used include Veratech®, Microprous polypropylene, Celgard®, or other polymers exhibiting similar properties. Other alternatives include Porex ®, woven or unwoven paper, synthetic or natural sponges, and an open cell foam.

Referring to now to Fig 3B, a blocking element 42 contains minor protrusions 43 that prevent the blocking element 42 from completely blocking every air hole 11 of the cell 10. The minor protrusions 43 create a gap 44 through which air can flow, or oxygen can diffuse, albeit, at a limited rate. The thickness of the gap 44 affects the rate by which the air flows, or the oxygen diffuses, through the gap 44. Reducing the rate by which air flows, or oxygen diffuses, through the gap 44 also reduces the rate by which oxygen diffuses through the air holes 11 of the cells 10.

Reducing the rate by which moisture diffuses through the gap 44 may reduce the rate by which the cells 10 desiccate. Moisture can diffuse out of the cells 10 through the air holes 11, thereby increasing the ppH_2O of the air in the

gap 44. Since the blocking element 42 decreases the rate by which the air in the gap 44 can be replenished with the less humid air from the atmosphere, the rate at which the cells 10 desiccate may decrease.

Although not illustrated, the same results may occur with a flat blocking element 42, without protrusions 43, and a cell 10 having minor protrusions on its first major surface 12.

Referring now to Figs. 3C and 3D, a blocking element 47 is made of an air permeable material and has open channels 48 that may run the entire length of the blocking element 47. When the blocking element 47 is placed against a cell 10, air can flow, or oxygen can diffuse, through the channels 48. Oxygen can then diffuse through the blocking element 47 and through the air holes 11 of the cells 10. Unlike the embodiment of Fig. 3A, air does not need to diffuse through a substantial part of the blocking element 47 to diffuse through the air holes 11 located at the center of the first major surface 12.

Referring now to Figs. 3E, 3F, and 3G, a spring 200, which is made of a conductive material, is embedded in a blocking element 201. In certain metal-air battery cells 10, the first major surface 12 acts as the cathode contact and the second major surface 13 acts as the anode contact. When the cell 10 is placed against the blocking element 201, the spring 200 is bent from its natural state to a shape similar to the shape of the spring in Fig. 3F. When the cell 10 is separated from the blocking element 201, the spring 200 is closer to its unstrained configuration.

The spring 200 serves at least two purposes. First, in embodiments where adjacent cells 10 are electrically connected in series with each other, the spring 200 connects the anode contact of one cell 10 with the cathode contact of the adjacent cell 10. This electrical contact is maintained even when the blocking element 201 is separated from the first major surface 12 of the cell 10. Second,

the spring 200 can also assist in the separation of the blocking element 201 from the first major surface 12. The forces that the spring 200 exerts on the cells 10 ensure that the cells 10 will separate.

Referring back to the embodiment of Figs. 2A and 2B, the casing 20 provides other benefits in addition to the benefits of controlling the cell's 10 access to air and reducing the rate of desiccation. When the casing 20 is in its second, expanded or open, configuration, the casing 20 is larger and extends further from the electronic device than when the casing 20 is in its first, compact or closed, configuration. When connected to a thin electronic device, the increased size of the casing 20 can make the combination of the electronic device and casing 20 easier to hold. The expanded casing 20 can provide a larger area for the user to grip the combination. Alternatively, and essentially providing the same benefit, the expanded configuration may provide more widely separated contact points on the hands and fingers of the user. This avoids the need, for example in cellular phones, for the user to align his or her fingers with the narrow body of the phone. The compact configuration provides the benefit of making the electronic device more portable.

Referring now to Fig. 4A, in an alternative embodiment similar to the embodiment of Figs. 2A - C, a casing 50 is in its first, compact or closed, configuration. The casing 50 has two major casing elements, a base 51 and a cover 52. The cells 10 are arranged in a parallel configuration so that the first major surfaces 12, with their respective air holes 11, face the base 51. The first major surfaces 12 of the cells 10 are placed against, or are positioned directly adjacent to, a respective flexible strip 53 or a blocking element 54, so that the air holes 11 of the cells 10 are at least partially blocked.

Referring now to Fig. 4B, the casing 50 is in its second, expanded or open, configuration. The flexible strips 53 and the blocking element 54 are separated from the first major surfaces 12 the cells 10.

Referring now to Fig. 5A, in an alternative embodiment similar to the embodiment of Figs. 2A and 2B, a casing 60 is in its first, compact or closed, configuration. The casing 60 has two major casing elements, a base 61 and a cover 62. A plurality of the flexible strips 63 is mounted to both the base 61 and the cover 62. Unlike the embodiment of Figs. 2A and 2B, the flexible strips 63 are attached to a flat major surface 64 on the base 61. A blocking element 65 is attached to the cover 62

Referring now to Fig. 5B, the casing 60 is in its second, expanded or open, configuration. The casing 60 opens and the flexible strips 63 and the blocking element 65 separate from the first major surfaces 12 of the respective cells 10.

Referring now to Fig. 6A, in an alternative embodiment similar to the embodiment of Figs. 5A and 5B, the flexible strips 63 of the embodiment of Figs. 5A and 5B, are performed by pairs of flexible strips 63A and 63B. The flexible strips 63A connect the cells 10 to the base 61. The flexible strips 63B connect the cells 10 to the cover 62.

Referring now to Fig. 6B, in an alternative embodiment similar to the embodiment of Fig. 6A, a casing 300 has two major casing element, a base 301 and a cover 302. Each of a plurality of flexible strips 303 and 304 attaches a respective on of the plurality of the cells 10 to the base 301 and the cover 302. The flexible strips 303 attach the second major surfaces 13 of the cells 10 to the base 301. The flexible strips 304 attach the first major surfaces 12 of the cells to the cover 302. Although not illustrated here, the flexible strips 303 and 304 can be connected to either one of the major casing elements 301 and 302 so their use is not limited to the illustrated example.

Referring now to Fig. 6C and 6D, the flexible strips 303 and 304 have contacts 305 embedded in the flexible strips 303 and 304. For cells 10 whose terminal contacts are integral with or coterminal with the surfaces of the cell, contacts 305 of the flexible strips 303 and 304 may connect the major surfaces 12 and 13 of the cells 10 to casing 300. Wiring in the casing 300 electrically connects the cells 10 in the desired arrangement.

Referring now to Fig. 7, in an alternative embodiment similar to the embodiment of Figs. 5A and 5B, a casing 70 has two major casing elements, a base 71 and a cover 72. Flexible strips 73 are connected to the base 71 and the cover 72. The base 71 and the cover 72 have apertures 74 through which the ends of the flexible strips 73 pass. The flexible strips 73 are attached to the outer surfaces of the base 71 and the cover 72. Attaching the flexible strips 73 to the outer surfaces of the base and cover 71 and 72 may make the casing 70 easier to manufacture. The apertures 74 are located on the base and cover 71 and 72 so that the cells 10 are substantially parallel with each other when the casing 70 is in its first, compact or closed, configuration. The benefit of arranging the cells 10 in a parallel configuration has been explained above.

Referring now to Figs. 8A and 8B, in an alternative embodiment, a casing 80 has two major casing elements, a base 81 and a cover 82. The base 81 and the cover 82 separate through the use of a plurality of springs 83 that serve the same function as the lever 30 of the embodiment of Figs. 2A and 2B. When the casing 80 is the first, compact or closed, configuration, the springs 83 are compressed. The casing 80 is maintained in the first, compact or closed, configuration by a latch 84 which prevents the springs 83 from separating the base 81 and the cover 82. The latch 84 can be released manually or automatically. The latch 84 can automatically release in response to an electrical signal indicating a decrease in the voltage of the battery, in response to a signal indicating the electronic device

has been turned on, or in response to an signal indicating that the electronic device is drawing, or is about to draw, more current. Releasing the latch 84 transforms the casing 80 from the first, compact or closed, configuration to the second, expanded or open, configuration.

The casing 80 may also have the capability to send a signal to the portable device, to which the portable device can respond. For example, the portable device can automatically turn on when the user manually transforms the casing 80 to its second, expanded or open, configuration. Such signaling can be provided by opening or closing contacts on the battery pack, by a voltage signal through a switch, or by other means.

Referring now to Fig. 8C, the latch 84 pivots with respect to pivot axis 85. A coil spring 86 keeps the latch 84 in the illustrated configuration. Pivoting the latch 84 around pivot axis 85 releases the latch 84. The springs 83 transforms the casing 80 to its second, expanded or open, position.

Referring to Fig. 9, in an alternative embodiment, a casing 90 has two major casing elements, a base 91 and a cover 92. A détente spring mechanism 93 transforms the casing 90 from its first, compact or closed, configuration to its second, expanded or open, configuration, and vice versa. One configuration of the détente spring mechanism 93 corresponds with the first, compact or closed, configuration of the casing 90 and the other configuration of the détente spring mechanism 93 corresponds to the second, expanded or open, configuration of the casing 90. A pivoting lever (not shown), similar to the pivoting lever of the embodiment of Figs. 2A-2C, is attached to the opposite end of the casing so that both ends of the cover 92 separate from respective ends of the base 91.

The cover 92 separates from the base 91 by manually rotating a lever 94, which is attached to the base 91 and the cover 92. The lever 94 rotates with respect to a pivot axis 95 from position 96 to position 97. Initially, a spring 98,

attached to a fixed point 99 on the base 91, resists the rotation of the lever 94. However, once the lever 94 rotates past the equilibrium point, the compressive forces of the spring 98 assists with the completion of the rotation of lever 94 to position 97. This détente mechanism 93 creates two distinct configurations for the casing 90. As in the embodiment of Figs. 2A and 2B, the shape of the base 91 prevents the lever 94 from over-rotating in either direction.

Other détente spring mechanisms can also provide the same effect. Examples of other détente spring mechanisms include single element spring "clickers", bi-morphs, etc.

Referring now to Figs. 10A and 10B, in an alternative embodiment, a casing 100 has two major casing elements, a base 101 and a cover 102. A plurality of the cells 10 is attached to the base 101 forming a first layer 103. A different and separate plurality of the cells 10 is attached to the cover 102 forming a second layer 104. The recesses of the base 101 hold the cells 10 of the first layer 103 in place. The recesses of the cover 102 hold the cells 10 of the second layer 104 in place. Although not illustrated here, other methods may be used to hold the cells in a designated position. For example, cell fixtures can attach and hold the cells 10 to the base 101 in a regular array.

The base 101 and the cover 102 are connected to and separated by a separation layer 106. This separation layer 106, which is attached to the perimeters of the base 101 and the cover 102, forms a plenum 105 between the first and second layers 103 and 104. The cells 10 of the first and second layers 103 and 104 are arranged so that their first major surfaces 12, containing the air holes 11, face the plenum 105.

It is preferred that the thickness of the plenum 105 be approximately 4 mm or more. Air can flow, or oxygen can diffuse, through the plenum 105 and provide the cells 10 with the oxygen needed to generate current.

The plenum 105 also serves other purposes. Separating the first major surfaces 12 of the cells 10 may be necessary to avoid electrical shorts. In certain prismatic metal-air cells, the first major surfaces 12 also act as the electrical contacts for the cathodes of the cells 10. Contacting the first major surfaces 12 of different cells 10 with each other, either directly or indirectly by a conductive element, may result in a short.

The arrangement of the cells 10 can reduce the likelihood of a short. A drop of water or other conductive element which touches the first major surfaces 12 of two cells 10 positioned directly across the plenum 105 from each other may cause a short. Increasing the distance between the cells 10 by increasing the thickness of the plenum 105 reduces the likelihood of a short. However, increasing the thickness of the plenum 105 also results in a larger battery casing.

One solution is to electrically inter-connect the cells 10 of the battery pack so that the first major surfaces 12 of the cells 10 positioned directly across the plenum 105 from each other are at the same nominal voltage with respect to ground. For example, referring to Fig. 10C, the cells 10 of first layer 103 are connected in series with each other. Likewise, the cells 10 of the second layer 104 are also connected in series with each other. The two sets of serially connected cells 10 are connected in parallel with each other. Since the cells 10 are essentially identical, each cell 10 should have approximately the same voltage difference between its anode and cathode. The voltage difference of the cathodes (not shown) of the cells 10 located at position 108A and 108D should be, nominally, the same with respect to ground. Likewise, the voltage difference of the cathodes (not shown) of the cells 10 located at position 108B and 108E should be, nominally, about the same. Likewise, for the voltages of the cathodes (not shown) of the cells 10 located at position 108C and 108F.

Referring back to Figs. 10A and 10B, arranging the cells 10 so that the first major surfaces 12, containing the air holes 11, face the plenum 105 may reduce the size of the casing 100. Creating one plenum 105 between the first and second layers 103 and 104 provides a low resistance to the flow of air because the plenum 105 is substantial in size (> 4mm) and the size of the plenum fuels the cells 10 of both layers 103 and 104. This eliminates the need and space for an additional plenum 105. For example, if the first major surfaces 12 of the cells 10 of the second layer 104 face away from the inner plenum 105, the cells 10 of the second layer 104 may need a separate plenum to ensure that these cells 10 have access to air. If there are four layers of cells 10, two plenums 105 may be used.

Referring now to Fig. 11A - D, in an alternative embodiment, a casing 110 has three major casing elements, a base 111, an inner cover 112 and an outer cover 113. The first major surfaces 12 of a plurality of the cells 10 face a plenum 114 that is substantially parallel to the base 111. The cells 10 maintain their designated positions via cell fixtures 115. The cell fixtures 115 connect the cells 10 to a base 111. The cell fixtures 115 also prevent the cells 10 from contacting each other and creating electrical shorts.

The inner cover 112 surrounds the arrangement of the cell fixtures 115 and the array of the cells 10. Although not shown in Figs. 11A – 11D, the inner cover 112 may also be attached to the base 111. The inner cover 112 has apertures 116 which allow for the free exchange of gases with the atmospheric air when the casing 110 is in the second, expanded or open, configuration. The inner cover 112 also has shutters 117 that protrude from a major surface 118 of the inner cover 112. The major surface 118 of the inner cover 112 also has apertures 119 that permit the ready exchange of gases with atmospheric air when the casing 110 is in the second, expanded or open, configuration. The outer cover 113 surrounds the inner cover 112. The outer cover 113 has apertures 120 and 121 which permit the

exchange of gases with the atmospheric air through the casing 110 when the casing 110 is in the second, expanded or open, configuration.

When the casing 110 is in the first, compact or closed, configuration, the outer cover 113 may be in direct contact with the base 111. The apertures 121 of the outer cover 113 are at least partially blocked by the surfaces of the inner cover 112. The apertures 116 of the inner cover 112 are at least partially blocked by the surfaces of the outer cover 113. The apertures 120 of the outer cover 113 are at least partially blocked by the shutters 117. The apertures 119 of the inner cover 112 are at least partially blocked by the surfaces of the outer cover 113.

When the casing 110 is in the second, expanded or open, configuration, the apertures 116 of the inner cover 112 line up with the apertures 121 of the outer cover 113, allowing air gases to exchange through the casing 110. Such exchange can also occur through the apertures 120 of the outer casing 113 and the apertures 119 of the inner casing 112.

Transforming the casing 110 from the first, compact or closed, configuration to the second, expanded or open, configuration can be accomplished by a spring and latch mechanism similar to the mechanism of the embodiment in Figs. 8A-C. Latches 124 keep the casing 110 in the first, compact or closed, configuration. When the latches 124 are released, a plurality of springs 123 separate the outer casing 113 from the base 111.

Blocking the apertures 116, 119, 120, and 121 of the inner and outer covers 112 and 113 when the casing 110 is in its first, compact or closed, configuration, to a full or limited extent, blocks the exchange of air gases between the cells 10 and the environment. This reduces the rate of desiccation. If a small volume of air is trapped inside, desiccation stops quickly, taking only the time needed for the moisture level in the small trapped volume to rise to equilibrium. If a large volume of air is trapped, desiccation can continue for a period of time after

the apertures are closed. Thus, if the casing 110 traps a large volume of air or the casing 110 is frequently opened and closed, the average rate of evaporation would tend toward a situation where the apertures were always open. As explained before, reducing the rate at which the cells 10 desiccates may increase the useful life of the cell 10.

If the ppH_2O of the trapped air is less than the ppH_2O of the trapped air (not shown) inside the cell 10, moisture will diffuse out of the cell 10. The rate at which this diffusion occurs is dependent, in part, on the gradient of ppH_2O across the first major surface 12 of the cell 10.

A casing 110 with a minimal volume of trapped air may be preferred. A casing 110 with less trapped air will require less moisture from the cells 10 to increase the ppH_2O of the trapped air to equilibrium. However, a casing 10 with too little trapped air, with complete sealing, can starve the cells 10 and cause the noted effects.

An electronic device's power requirements should be considered when designing a configuration for a battery casing. For example, using the same cellular phone's power requirements used in the example above, a typical cellular phone, when turned off, only requires 0.5 cc/hr to prevent the cells 10 from entering a prolonged state of powerlessness. Enclosing a minimal amount of trapped air, as when the casing 110 is in the first, compact or closed, configuration, may provide the air cathodes (not shown) of the cells 10 with a sufficient oxygen supply to avoid this effect. Again, this applies where the closed configurations admit too little air to allow this minimal diffusion rate. This would be good for long shelf-life systems.

Likewise, for low current loads, the first, compact or closed, configuration of the casing 110 may also provide the cells 10 with enough trapped air 122 to operate for a significant length of time. For cellular phones with higher current

demands, the casing 110 may need to be in its second, expanded or open, configuration to provide the cells 10 with a sufficient supply of oxygen.

Referring now to Fig. 11E, 11F, and 11G, in an alternative embodiment similar to the embodiment of Figs. 11A – 11C, a casing 110 has two sets of shutters, 125 and 126. When the casing 110 is in the second, expanded or open, configuration, the shutters 125 and 126 separate from each other and permit air to flow, or oxygen to diffuse, through apertures 127 adjacent to the shutters 125 and 126.

Referring now to Fig. 12A, in an alternative embodiment, a casing 130 has grooves 133 on its cover 131. Although the grooves 133 of this embodiment extend the entire length of the casing 130, similar results may be obtained using grooves 133 having shorter lengths. Within the recesses of the grooves 133 are air holes 134 that provide a means for air to enter and exit the casing 130. Embedding the air holes 134 in the recesses of the grooves 133 may prevent the air holes 134 from being completely blocked when the casing 134 is pressed against a flat surface or held in the hand.

Referring now to Fig. 12B, air can flow or oxygen can diffuse between the grooves 133 and through the air holes 134 even when the casing 34 is placed against a flat surface 135. By ensuring that the air holes 134 cannot be completely blocked, the casing 130 can be designed to contain fewer holes. It is not necessary to design a casing with an excessive number of air holes or increase the size of air holes to ensure that the cells 10 are provided with sufficient access to air. Reducing the size and/or number of air holes can also reduce the likelihood that unwanted particles will enter the casing 130.

Referring now to Fig. 13, in an alternative embodiment, a casing 140 has an air deflector 141 that deflects air into the casing 140. The air deflector 141 is attached to the casing 140 by a hinge 142 that allows the air deflector 141 to

pivot. The air deflector 141 can be stored against the relatively flat surface 143 of the casing 140 when the cellular phone is not in use. It can also serve to direct the user's voice into the microphone when the cellular phone is in use.

The air deflector 141 deflects air into an opening 144 on the casing 140. Air can also exit the casing 140 through an opening 145. In a typical cellular phone configuration, the cellular phone user propels air through the air opening 144 through normal speech.

Referring now to Figs. 14A and 14B, in an alternative embodiment similar to the embodiment of Figs. 10A and 10B, a casing 150 consists of two major casing elements, a base 151 and a cover 152. A plurality of the cells 10 is attached to the base 151 forming a first layer 155. A plurality of the cells 10 is attached to the cover 152 forming a second layer 156. The first major surfaces 12 of the plurality of the cells 10 face an inner plenum 153. Surrounding the cells 10 are filler elements 154. The filler elements 154 fill the gaps between the cells 10 of the first layer 155 and the base 151 and the gaps between the cells 10 of the second layer 156 and the cover 152. The filler elements 154 may be hard foam that is sufficiently resilient that it can hold the cells 10 in place and thereby eliminate the need of a separate support structure.

The casing 150 has an entrance opening 157 and an exit opening 158. The entrance opening 157 is located on one side of the casing 150 in close proximity to the inner plenum 153. An air permeable material (not shown) covers the entrance opening 157. The air permeable material permits air to flow into the casing 150 and prevents water and other undesirable elements from entering the casing 150. The exit opening 158 is located on the opposite side of the entrance opening 157 and in close proximity to the opposite side of the inner plenum 153.

A fan 159 is located near the entrance opening 157 of the casing 150. When the fan 159 is operating, air enters through the entrance opening 157 and

exits through the exit opening 158. The cells 10 power the fan 159. It is preferred that the fan 159 operates only when high levels of current is demanded, such as when the electronic device is turned on.

The fan 159 consists of a motor 159A and an attached fluttering element 159B. The motor 159A oscillates the fluttering element 159B so that the fluttering element 159B flexes in a transverse wave like motion. The flutter element 159B propels air towards the exit opening 158.

Referring now to Fig. 14C, the filler element 154 has recesses 154A that hold the cells 10 in place. The depth of the recesses 154A are as deep as the thickness of the cells 10 so as to create a relatively flat plane when the cells 10 are placed in the recesses 154A. The shape of the recesses 154A also mirrors the shape of the cells 10.

Although not illustrated here, a thin layer of an air permeable material (not shown) can be placed over the first major surface 12 of the cells 10. The air permeable material (not shown) permits air to diffuse through the material and through the air holes 11 of the cells 10. The air permeable material (not shown) can also reduce to rate that moisture diffuses out of the cells 10. Examples of materials that may be used include Porex ®, woven or non-woven cloth, open cell foam, etc.

The filler elements 154 serve a number of purposes. First, the filler elements 154 can smooth the shape of the inner plenum 153 by eliminating a number of recesses created by the gaps surrounding the sides of the cells 10. A smoother inner plenum 153 may create a more fluid air flow and eliminate the need to design a thicker plenum 153 to ensure that oxygen rich air from the atmosphere flows over every cell 10. A thicker inner plenum 153 takes up more space and can increase the size of the casing 150. Second, a smoother inner plenum 153 may also decrease the energy consumed by the fan 159 to propel air

through the plenum 153. Third, the filler elements 154 can also be used to hold the cells 10 in the desired array, thereby eliminating the need for cell fixtures. Fourth, although not necessary in the present embodiment, the filler elements 154 may also reduce the volume of trapped air in embodiments where trapping a minimal volume of trapped air in the casing can reduce the rate at which the cells 10 desiccate. Finally, the filler elements 154 can behave as a diaper and absorb liquids that contact or may contact the cells 10.

Under normal conditions, the liquid electrolyte (not shown) contained in the cells 10 remain inside the cells 10. However, under more extreme conditions, such as when the cells 10 are exposed to high temperatures or excessive forces, electrolyte may leak out of the cells 10. The filler elements 154 absorb the electrolyte, thereby preventing the electrolyte from penetrating the casing 150 and coming into contact with the user's hands. The filler elements 154 also absorb moisture from the atmosphere that may have penetrating the casing 150.

The filler elements 154 can be coated with a layer of polyurethane, or an alternative liquid-impermeable material. The coating separates the cells 10 from moisture that is absorbed by the filler elements 154, thereby reducing the chance that the absorbed liquid will cause a short. It is preferred that the coating not be applied to the surfaces of the filler elements 154 that face the inner plenum 153 since that would defeat the purpose of using an absorbent material as a filler elements 154. In an alternative to a coating of polyurethane, the filler elements 154 can also be placed in a tray shaped to fit the filler elements 154

The filler elements 154 may reduce the rate by which the cells 10 desiccate. If the filler elements 154 remain moist, moisture from the filler elements 154 may increase the ppH_2O of the air immediately above the air holes 11 of the cells 10, thereby decreasing the ppH_2O gradient across the first major surfaces 12.

Referring now to Fig. 15A – 15E, in an alternative embodiment, a casing 160 consists of two major casing elements, an inner sleeve 161 and an outer sleeve 162. A plurality of the cells 10 is arranged so that every cell 10 is substantially parallel with the others.

The cells 10 are separated from each other by a plurality of springs 163. Each spring 163, with the exception of the springs 163 at locations 164 and 165, are compressed against one of two major surfaces 12 or 13 of one cell 10 and against one of two major surfaces 12 or 13 of an adjacent cells 10. The springs 163 at locations 164 and 165 are compressed against one major surface 12 or 13 of one cell 10 and a surface on either the inner sleeve 161 or the outer sleeve 162. The springs 163 are in a compressed state when the casing 160 is in the first, compact or closed, configuration.

Some of the springs 163 can also electrically connect adjacent cells 10 in series. In certain metal-air battery cells 10, the first major surface 12 acts as the cathode contact and the second major surface 13 acts as the anode contact. The springs 163 maintain contact with the first and second major surfaces 12 and 13 of the cells.

Examples of the springs 163 are shown in Figs. 15F and 15G. Figs. 15F and 15G show two different leaf springs 174 between the cells 10. Each leaf spring 174 is made of two curved and elastic elements 175 that are connected to each other. The two elastic elements 175 can be made of a conductive material or made of a non-conductive material with a conductive coating. The two elastic elements 175 can electrically connect two adjacent cells 10 in series by electrically connecting the elastic elements at point 176. The elastic elements 175 can also be insulated from each other at point 176, with each elastic element 175 electrically connected to the casing 160. The wiring in the casing 160 can connect the plurality of the cells 10 in the desired arrangement.

Other examples of the springs 163 are shown in Figs. 15H and 15I. Fig. 15H shows a concave shaped spring 177 between the cells 10. The concave shaped spring 177 is compressible and at least partially blocks the air holes 11 of an adjacent cell 10. Fig. 15I shows a spring with standoffs 178 between the cells. The spring with standoffs 178 is also compressible and at least partially blocks the air holes 11 of an adjacent cell 10. Both the spring with standoffs 178 and the concave spring 177 perform a blocking function similar to the blocking element 25 of the embodiment of Fig. 2A when they are compressed. The standoffs provide some space for low rate of gas diffusion.

Referring back to Figs. 15A – 15E, the inner sleeve 161 has openings 166 and 167. The opening 166 has a width 168 that is less than the width of the cells 10, thereby reducing the likelihood that dislodged cells 10 will fall out through the opening 166. The opening 166 permits air to enter and exit the casing 160, or oxygen to diffuse into the casing 160, when the casing 160 is not in the first, compact or closed, configuration. The inner sleeve has grooves 171 on at least two of its sides. The cells 10 may slide through the opening 167 when the casing 160 assumes a different configuration.

The outer sleeve 162 has openings 168 and 169. The opening 168 has a width 170 that is less than the width of each cell 10. The opening 168 permits air to enter and exit the casing 160, or oxygen to diffuse into the casing 160, when the casing 160 is not in the first, compact or closed, configuration. The outer sleeve 162 also has recesses 172 that complement, and can slide along the grooves 171, of the inner sleeve 161.

When the casing 160 is in its first, compact or closed, configuration, the outer sleeve 162 blocks the opening 166 and the inner sleeve 161 blocks the opening 168. In the compact configuration, the casing 160 limits the exchange of air gases between the cells and the environment when the electronic device

requires little or no current have been explained above. Thus, desiccation is limited when the device does not need the high current, such as when it is stored.

A latching mechanism 173 keeps the casing 160 in its first, compact or closed, configuration. The latching mechanism 173 can be similar to the latching mechanism of the embodiment of Fig. 8C. When the latching mechanism 173 is released, the springs 163 slide the outer sleeve 162 along the path dictated by the grooves 171 and the recesses 172.

Referring now to Fig. 15D, the grooves 171 and the recesses 172 control the motion of the outer sleeve 162 as it slides with respect to the inner sleeve 161. Sliding the outer sleeve 162 transforms the casing 160 from the first, compact or closed, configuration to the second, expanded or open configuration, and vice versa.

Referring now to Fig. 15E, the casing 160 is in its second, expanded or open, configuration. The openings 166 and 168 are relatively unblocked and gases can exchange through the openings 166 and 168.

One advantage of arranging the cells 10 and the springs 163 in this accordion like configuration is that the cells 10 and the springs 163 can permit the cells 10 to oscillate when the casing 160 is moved in the ordinary course of use. Oscillating the cells 10 circulates fresh air in through the casing 160 and can therefore, increase the rate at which oxygen is exchanged through the air holes 11 of the cells 10.

Referring now to Fig. 16A, a casing 180 has two major elements, a base 181 and a cover 182. The base 181 and the cover 182 have air holes 187. Attached to the base 181 is a plurality of the cells 10 forming a first layer 183. Attached to the cover 182 is a plurality of the cells 10 forming a second layer 184. The first major surfaces 12, containing the air holes 11, face a plenum 185. Air can flow, or oxygen can diffuse, through the plenum 185.

Attached to the base 181 is a blocking element 186. The blocking element 186 is positioned in the plenum 185. The blocking element 186 serves essentially the same function as the flexible strips 23 and the blocking element 25 of the embodiment in Figs. 2A and 2B. When the casing 180 is in the second, expanded or open configuration, air can enter or exit the casing 180, or oxygen can diffuse into the casing 180, through the air holes 187 or through an opening 188 defined around the perimeter of the base 181. Air can flow, or oxygen can diffuse, through the plenum 185.

Referring now to Fig. 16B, the casing 180 is the first, compact or closed, configuration. The first major surfaces 12 of the cells 10 of the second layer 184 press against and stretch the blocking element 186. The blocking element 186 also presses against the first major surfaces of the cells 10 of the first layer 183. The blocking element 184 may be made of an open cell foam.

Referring now to Fig. 16C, in an alternative embodiment similar to the embodiment of Figs. 16A and 16B, a casing 180A consists of two major casing elements, a base 181A and a cover 182A. Unlike the embodiment of Figs. 16A and 16B, the base 181A overhangs the cover 182A. A blocking element 186A, which is attached to the cover 182A, at least partially blocks the air holes 11 of the cells 10 when the casing 180A is in the first, compact or closed, position.

Referring now to the Fig. 16D, in an alternative embodiment similar to the embodiment of Figs. 16A and 16B, a casing 180B consists of two major casing elements, a base 181B and a cover 182A. Neither the base 181B nor the cover 182B overhangs each other. A blocking element 186B is attached to the base 181B and at least partially blocks the air holes 11 of the cells 10 when the casing 180B is in its first, compact or closed, configuration. Although not illustrated here, the blocking element 186B can be attached to the cover 182B instead of the base 181B.

Referring now to Fig. 17A and 17B, in an alternative embodiment, a casing 190 consists of two major casing elements, a base 191 and a cover 192. A hinge 193 attaches the base 191 to the cover 192. When the casing 190 is in its second, expanded or open, configuration, air can flow between the base 191 and the cover 192. Unlike the embodiment of Figs. 2A and 2B, the base 191 remains in contact with the cover 192 through the hinge 193.

In an alternative embodiment not shown but applicable to many of the foregoing embodiments, a casing is made entirely of, or partly of, an air permeable, hydrophobic material. The material contains pores that permit air gases to diffuse or flow through the casing and small enough to prevent water from dripping into the casing due to surface tension. Porex® is an example of a suitable material. The thickness and the surface area of the casing are factors to consider when choosing a material. Ideally, the casing has a hydrophobic surface.

Referring now to Fig. 18A, in an alternative embodiment, a casing 210 is in its first, compact or closed configuration. The casing 210 has two major casing elements, a base 211 and a cover 212. A plurality of the cells 10 is attached to either the base 211 or the cover 212, but not to both. The cells 10 are arranged so that every cell 10 is substantially parallel to the others. Every other cell 10, in an uninterrupted series, is attached to the cover 212 and the remaining cells 10 are attached to the base 211.

The cells 10 are attached to the base 211 or the cover 212 by recesses 213 in the base 211 or the cover 212. However, the cells 10 can also be attached by snap fit into the recesses 213 or by an adhesive. Within the recesses 213 are contacts that connect to the anode contact (not shown) and the cathode contact (not shown) of the cells 10. The cells 10 are removable from the recesses making the embodiment semi-permanent. When the cells 10 are no longer able to

generate the necessary current to power the electronic device, the cover 212 can be detached and the cells 10 can be replaced.

Referring now to Fig. 18B, the casing 210 is in the second, expanded or open, configuration. The cover 212 is separated from the base 211 creating an opening 214 defined around the perimeter of the base 211. The less compact arrangement of the cells 10 permits the air to flow, or oxygen diffuse, more freely over the air holes 11 of the cells 10.

Referring now to Fig. 19A, in an alternative embodiment, a casing 220 has two configurations, a closed configuration and an open configuration. The casing 220 has two major casing elements, a base 221 and a cover 222. A plurality of the cells 10 is arranged so that the first major surfaces 11 of the cells 10 face a plenum 223. Two side apertures 224 on the cover 222 permit air to enter, or oxygen diffuse into, the casing 220.

Spring hinges 225 are attached to blocking elements 226 and to the inner surface of the cover 222. The spring hinges 225 pivot the blocking elements 226 so that the blocking elements 226 at least partially block the apertures 224. Blocking the apertures 224 prevents the flow of air and the diffusion of moisture through the casing 220.

Referring now to Fig. 19B, an activation bar 227 consists of a hinge 228 and a peg bar 229, which has a plurality of pegs 230. The activation bar 227 is attached to the cover 222 via the hinge 228.

Referring now to Fig. 19C, the peg bars 229 pivot around the hinges 228. The pegs 230 pass through the apertures 224 and open the casing 220 by pushing the blocking elements 226 away from the apertures 224. Opening the casing 220 permits the exchange of gases through the casing 220. This open configuration is preferable when the cells 10 require more oxygen to generate higher levels of current, such as when the electronic device is on.

When the cells 10 require little oxygen, it is preferable that the casing 220 be in the closed configuration. Closing the casing 220 may decrease the rate by which the cells 10 desiccate. The spring hinges 225 pivot the blocking elements 224 and push the pegs 230 back out of the casing 220 through the apertures 224.

In a metal-air battery configuration for use in a cellular phone, it is preferable that when the cellular phone is off or in standby mode, the spring hinges 225 pivot the blocking elements 224 so that the blocking elements 224 at least partially block the apertures 224. When the phone is picked up by the user, the user's hand push the pegs 230 into the casing 220 via the activation bars 227. The pegs 230 push the blocking elements 224 away from the apertures 224, and air can enter, or oxygen can diffuse into, the casing 220. The activation bars 227 are located so that a natural holding of the electronic device causes the activation bars 227 to be pressed.

Referring now to Fig. 19E, in an alternative embodiment similar to the embodiment of Figs. 19A-D, flexible blocking elements 231 are attached to the inner surfaces of the cover 222 by attaching elements 232. Unlike the embodiment of Figs. 19A-D, spring hinges 225 are not needed. Instead, the flexible blocking elements 231 are resilient enough to act as springs so that the flexible blocking elements 231 force the pegs 230 out of the apertures 224 when they return to their original shape. The flexible blocking elements 231 are attached to the cover 222 so that the flexible blocking elements 231 at least partially block the apertures 224 when the pegs 230 are not bending the flexible blocking element 231.

Still another alternative is to have the blocking element and the pegs formed as integral elements so that when the pegs are pushed inside, the tops, which would have the appearance of the tops of nails, would unseal the opening.

Referring now to Fig. 20, in an alternative embodiment, a casing 240 has a plurality of air holes 243. The cells 10 are arranged to form two layers, a first layer 241 and a second layer 242. The cells 10 of the first layer 241 are substantially parallel to the cells 10 of the second layer 242. Unlike the embodiment of Figs. 10A and 10B, the first major surfaces 12 of the cells 10 do not face each other. Instead, the second major surfaces 13 of the cells 10 of the first layer 241 face the second major surfaces 13 of the cells 10 of the second layer 242. The first major surfaces 12 of the cells 10 of both layers 241 and 242 face the casing 240.

The cells 10 are held in place by cell fixtures 244. However, the cells 10 may also be held in place by the casing 240. The casing 240 can be shaped to conform to the shape of the cells 10, thereby eliminating the need for the cell fixtures 244. The air holes 243 of the casing 240 provide the cells 10 with access to air.

The casing 240 is attached to the electronic device by a plurality of casing fixtures 245. The casing fixtures 245 position the casing 240 apart from the electronic device, creating a gap 246. Air that flows, or oxygen that diffuses, through the gap 246 may eventually diffuse through the air holes 11 of the cells 10 of the first layer 241.

Referring now to Fig. 21A, in an alternative embodiment for use in a hands-free environment, a cellular phone 251, having a outlet 252, is attached to a metal-air battery pack 253 having a sliding switch mechanism 254. The metal-air battery pack 253 also has shutters 255.

In a hands free environment, the cellular phone 251 is connected to an outlet connector (not shown) via the outlet 252. In many hands-free environments, the outlet connector (not shown) connects the cellular phone 251 to a separate microphone, antenna, and speaker. The cellular phone user can operate

the cellular phone 251 without having to hold the cellular phone 251, thereby creating a hands-free environment. In many hands-free environments, the outlet (not shown) also provides the cellular phone 251 with the power to operate the phone, eliminating the need for the battery pack 253. In some instances, the outlet connector (not shown) can recharge a secondary battery attached to the phone.

However, attempting to charge the metal-air battery pack 253 may shorten the useful life of the cells 10 contained in the battery pack 253. Most metal-air battery cells 10 are not suitable and not designed to be recharged.

The sliding switch mechanism 254 attached to the battery pack 253 can reduce the likelihood that the cells 10 in the battery pack 253 will be accidentally "recharged." The sliding switch mechanism 254 can also act as a communicating means to the shutters 255 of the battery pack 253, communicating to the shutters 255 when to open or close. When the outlet 252 of the battery pack 253 is attached to the outlet connector (not shown), the outlet connector (not shown) provides the cellular phone 251 with the energy to operate.

Referring now to Fig. 21B, a button 255, which is held in place by a spring 257, prevents a switch 256 from sliding along a groove (not shown). When the switch 256 is in this position, the battery pack 253 is electrically disconnected from the cellular phone 251; the outlet 252 of the cellular phone 251 can be connected to the outlet connector (not shown); and the shutters 255 are closed. Disconnecting the battery pack 253 prevents the cells 10 contained in the battery pack 253 from accidentally "recharging." Closing the shutters 255 slows the rate at which the cells 10 desiccate.

Referring now to Fig. 21C, the switch 256 slides to cover the outlet 252, blocking the outlet connector (not shown) from connecting to the outlet 252. Sliding the switch 256 is accomplished by simultaneously pressing the button 255 and sliding the switch 256. When the switch 256 is in the illustrated position, the

shutters 255 are open and the battery pack 253 is electrically connected to the cellular phone 251.

As an alternative to embodiment of Fig. 21A, a mold can be inserted in the outlet to prevent the user from attaching a recharging outlet connector to the phone.

Referring now to Fig. 22, in an alternative embodiment, a battery pack 260 is attached to a rechargeable battery 261, which is attached to a cellular phone 262. When the battery pack 260 is attached to the rechargeable battery 261, the battery pack 260 powers the cellular phone 262 and recharges the rechargeable battery 261. The battery pack 260 can be attached to the rechargeable battery 261 by a latching mechanism (not shown). In certain cellular phone/rechargeable battery configurations, it may be necessary to connect the battery pack 260 to the cellular phone 262 instead of the rechargeable battery 261.

A cellular phone user can attach the battery pack 260 to the rechargeable battery 261; operate the cellular phone 262 and recharge the rechargeable battery 261; and later disconnect the battery pack 260 from the rechargeable battery 261 when the recharging is complete. The cellular phone 262 can then operate on the power from the rechargeable battery 261.

Besides the benefits of the embodiment described above, the battery pack 261 also provides ergonomic benefits by making the embodiment easier to hold. The combination of a rechargeable battery 261 and a battery pack 260 also provides other benefits. The combination can provide the cellular phone 262 with high bursts of power that the rechargeable battery 261 or the battery pack 260 may not be able to provide alone. High bursts of power are needed when the cellular phone 262 rings.

Referring now to Fig. 23A, the schematic diagram of the control circuit shows a plurality of batteries 330 connected in series, an auxiliary battery 331, a

control unit CU, an amp-meter A, a volt meter V, an output C, and two switches S1 and S2. This control circuit for a metal-air battery pack prevents the electronic device user from inadvertently charging the battery pack. The control circuit also provides for additional power through an auxiliary battery when more power is needed. The control circuit measures the flow of current through the circuit and also the voltage across the electronic device via the amp-meter A and the volt meter V. The control unit CU can also send a signal to output C to control the opening and closing of shutters in shuttering embodiments, the opening or closing of the casing in clamshell type embodiments, or the operation of a fan in certain active flow embodiments. One or more of the batteries 330 or 331 can be disconnected from the circuit via the switches, S1 and S2. The switches S1 and S2 open or close the circuit in response to a signal from the control unit CU, and the control unit CU sends a signal to the switches S1 and S2 based upon signals from the amp-meter A , the volt meter V, and/or the electronic device.

The control circuit has three modes of operation, an off mode, a low mode, and a high mode. The control unit CU switches the circuit between the different modes. When the circuit is in the off mode, both the switches S1 and S2 are open and the batteries 330 and 331 are electrically disconnected from the electronic device. When the circuit is in low mode, switch S1 is closed and switch S2 is open. The batteries 330 are connected to the electronic device. When the circuit is in high mode, switch S1 is open and switch S2 is closed. The batteries 330 and 331 are connected to the electronic device.

If the control unit CU senses a flow of current in the reverse direction of normal discharge, the control unit CU switches the circuit into off mode. A flow of current in the opposite direction may indicate that the user is attempting to recharge the battery pack. To prevent the recharging of the batteries 330 and 331,

the control unit CU opens the switches S1 and S2, which opens the control circuit and stops the flow of current through the batteries 330 and 331.

When the volt meter sense a voltage of 0 across the electronic device and the circuit is in off mode, the control unit switches the circuit to low mode. A voltage of 0 across the electronic device may indicate that the electronic device has been disconnected from the recharging device. When voltage across the electronic device is above 4.5 volts for more than 30 seconds, the control unit CU switches the circuit to low mode. When the voltage across the electronic device drops below 3.6 volts, the control unit CU switches the circuit to high mode.

While not necessary to practice the invention, it is preferable that the circuit is configured to contain certain quantitative limitations, depending on the power requirements of the electronic device. For example, in a typical cellular phone, it is preferable that the switching time will be less than 0.5 μ seconds. It is preferable that switching between high mode and low mode is accomplished by first closing the open switch and then opening the closed switch, thereby ensuring that the electronic device will not become disconnected during the switching process. It is also preferable that the voltage drop across the switch S2 will not exceed 20mV at 2A, and the voltage drop across the switch S1 will not exceed 50mV at 0.3A. It is preferable that the control unit CU send a signal to output C to open the shuttering mechanism, expand the casing in a clamshell embodiment, or turn on the fan when average current through the circuit is greater than 0.2A for more than 20 seconds. This ensures adequate air access during higher current demands. Likewise the control unit CU closes the shutters, compacts the casing, or turns off the fan when the current is less than 0.1A for more than 20 seconds.

Referring now to Figs. 23C and 23D, in an alternative embodiment, the battery pack has switches S3, which is connected to the electrical circuitry of the battery pack and controls the voltage of the battery pack. The switches S3 can be

toggled manually or in response from an electrical signal from the electronic device. Different electronic devices operate on different voltages, making one battery configuration suitable for only a very limited number of electronic devices. Fig. 23C shows four cells 10 connected in series. Toggling the switches S3 converts the four cells 10 into two sets of two serially connected cells 10, which are connected in a parallel configuration as illustrated in Fig. 23D.

In an alternative embodiment, the switch can be connected to a control unit of an electrical schematic similar to the embodiment of Fig. 23A. The position of the switch determines the operating voltage through which the control unit either connects or disconnects one or more auxiliary cells.

The electrical circuitry to convert the voltage of the battery pack to the operating voltage of the electronic device can be incorporated into a disposable battery pack. The circuitry is then discarded after the cells 10 are expended. To reduce cost, the electrical circuitry can also be incorporated into a semi-permanent battery casing or incorporated into the electronic device, itself. The circuitry can be reused several times by replacing the cells 10 in a semi-permanent design or by replacing the battery pack in latter mentioned design.

Referring now to Fig. 24A and 24B, embedded in a single cell casing 350 are two spring contacts 351 and 352. A plurality of the single cell casings 350 with cells 10 is housed in the battery casing (not shown). The spring contact 351 of the single cell casing 350 is connected to the anode (not shown) of the cell 10 and the spring contact 352 is connected to the cathode (not shown) of the cell 10. Wiring 355 connects the plurality of the cells 10 via the spring contacts 351 and 352 of the plurality of the single cell casings 350. The single cell casing 350 has two apertures 353 and 354. The aperture 353 permits oxygen from outside the single cell casing 350 to diffuse through the air holes 11 of the cell 10 housed in

the single cell casing 350. In fact, it is preferred that the aperture 353 be large so that the singe cell casing 350 blocks the least number of air holes 11.

The single cell casing 350 is an inexpensive solution to the problem of electrically connecting the individual cells 10. It eliminates the need to solder insulated bus bars or wiring directly onto the cell 10, making the battery casing (not shown) easier to manufacture.

It can also reduce the cost of powering an electronic device with metal-air cells. When the cells 10 are dead, the user can open the battery casing (not shown) and replace the dead cells 10. The user can re-use the battery casing (not shown), the single cell casings 350, the wiring 355, etc., thereby, making the embodiment semi-permanent.

The single cell casing 350 can also apply external pressure on the cell 10. Experiments have shown that metal-air battery cells 10 are able to generate more energy when external forces are applied.

Referring now to Figs. 24A and 24C, the cell 10 can enter and exit the single cell casing 350 through the aperture 354. A ridge 356 located on the single cell casing 350 snaps the cell 10 in place. The cell 10 can be removed by simultaneously pressing against the first major surface 11 of the cell 10 - which compresses the spring contact 351 - and sliding the cell 10 out through the aperture 354. However, if the cell 10 is not shaped as the cell 10 illustrated in Figs. 24A - 24B, the same result can be accomplished using the single cell casing 350 illustrated in Fig. 24D.

Referring now to Fig. 25A and 25B, a cell clip 360 is attached to a single cell 10 via two arms 364, which are engaged in two notches 361 located on the side of the cell 10. Spring contacts 362 and 363 contact the cathode contact and the anode contact of the cell 10, respectively. Wiring 365 connects the plurality

of the cells 10 via the spring contacts 362 and 363 of the plurality of cell clips 360.

The notches 361 are located in center of the side of the cell 10 so that the cell clip 360 can be attached to the cell 10 from both directions. The cell clip 360 can be made of plastic or an alternative resilient material so that the cell 10 can be snap-fitted between the arms 364. As in the embodiment of Figs. 24A- 24B, the user can manually replace the dead cells 10.

Referring now to Fig. 25C, in an alternative embodiment similar to the embodiment of Figs. 25A and 25B, a cell clip 370 completely surrounds the perimeter of the cell 10, eliminating the need for notches 361. Spring contacts 371 can flex so that the user can replace the cell 10 by bending the spring contacts 371 and sliding the cell 10 out of the cell clip 360.

Referring now to an alternative embodiment not shown, a leather holster can hold the combination of the electronic device and battery pack. The holster can surround the combination and restrict the airflow through the battery casing, thus reducing the rate at which the cells 10 desiccate. The holster can be attached to a carrying strap or attached to a bag or an article of clothing. The holster provides a convenient and esthetically pleasing alternative to holding the electronic device in the user's hands, while providing protection and air access control benefits.

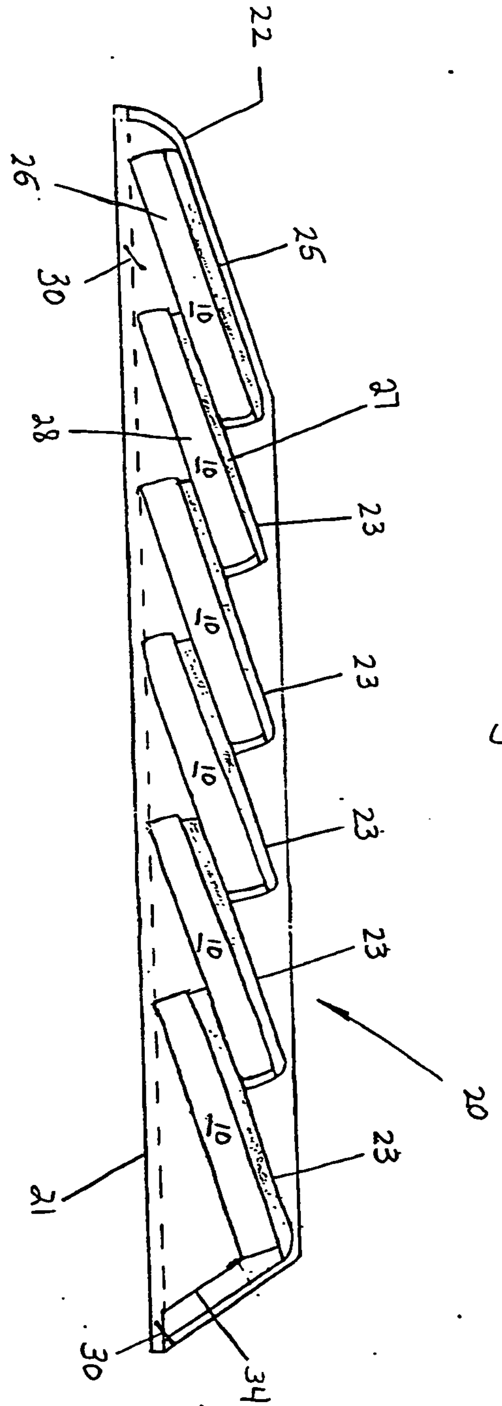

Fig. 2A

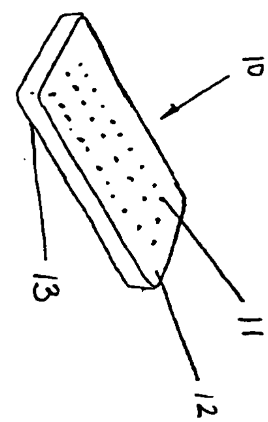

Fig 1

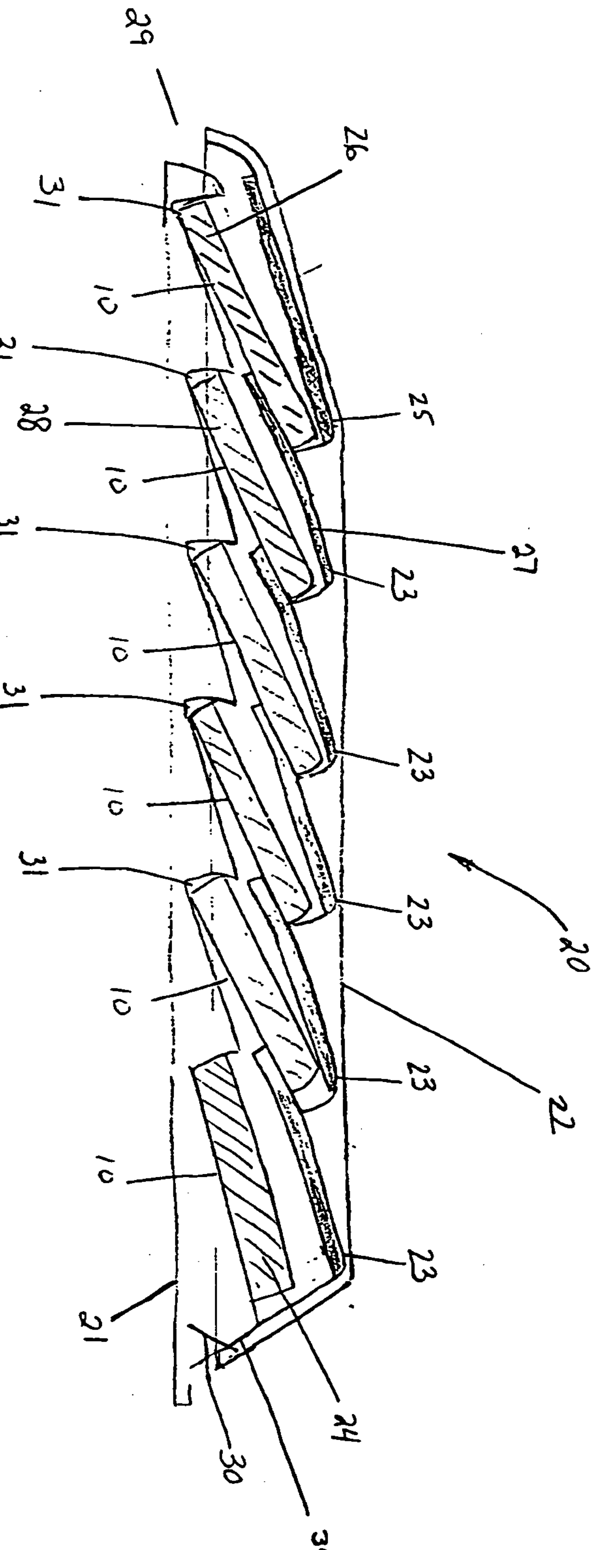
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Fig 2B

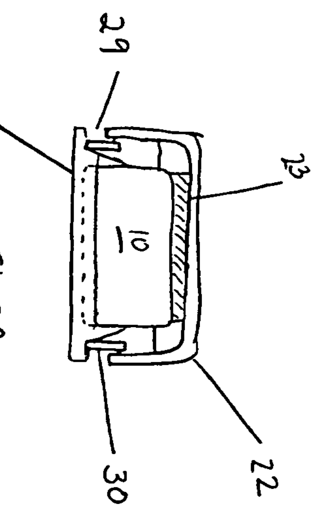


Fig 2C

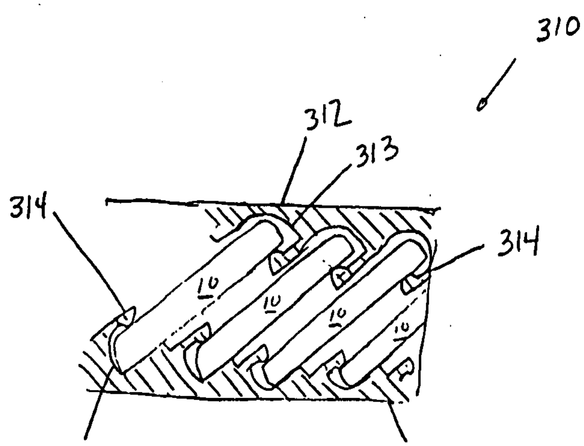


Fig 2D

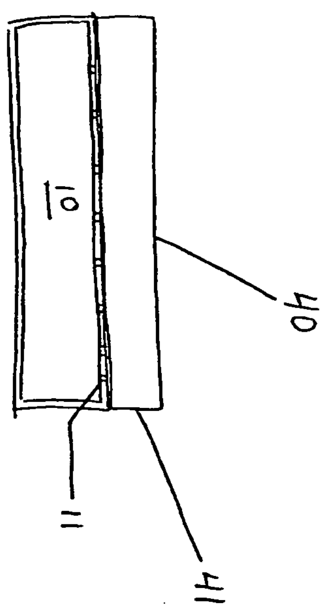


Fig 3A

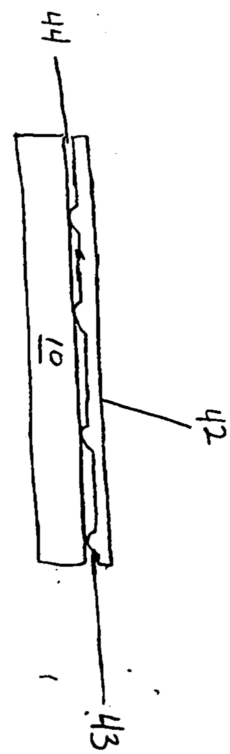


Fig 3B

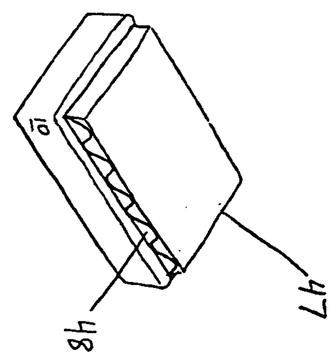


Fig 3C

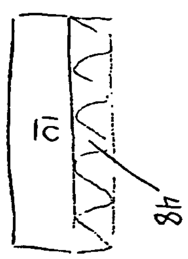


Fig 3D

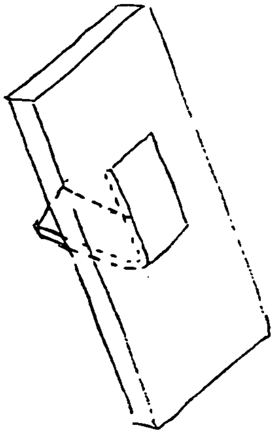


Fig 3G

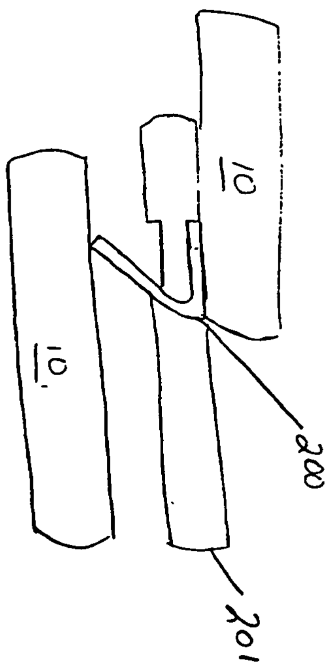


Fig 3E

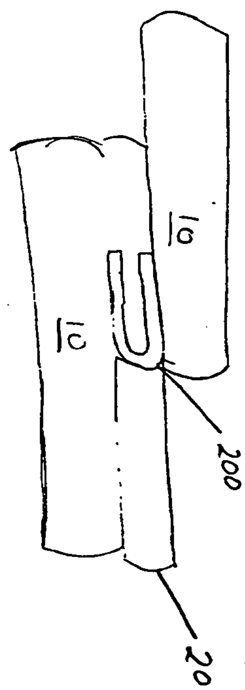


Fig 3F

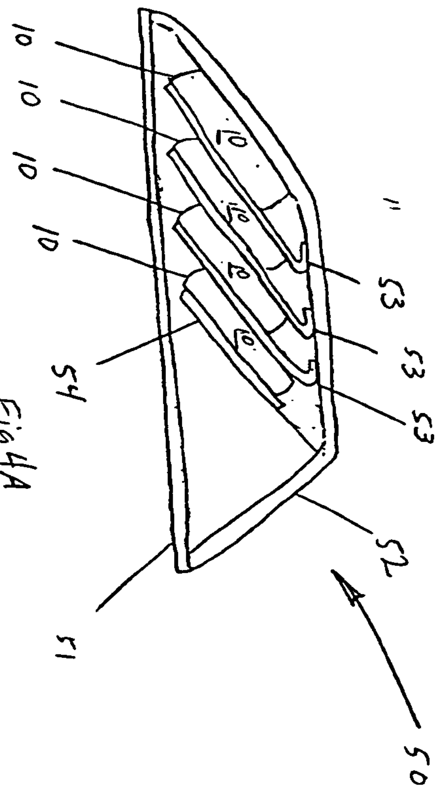


Fig 4A

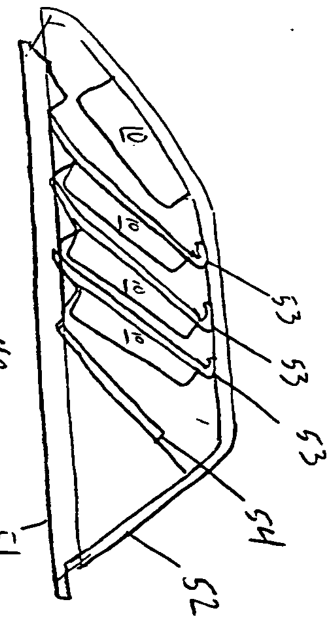


Fig 4B

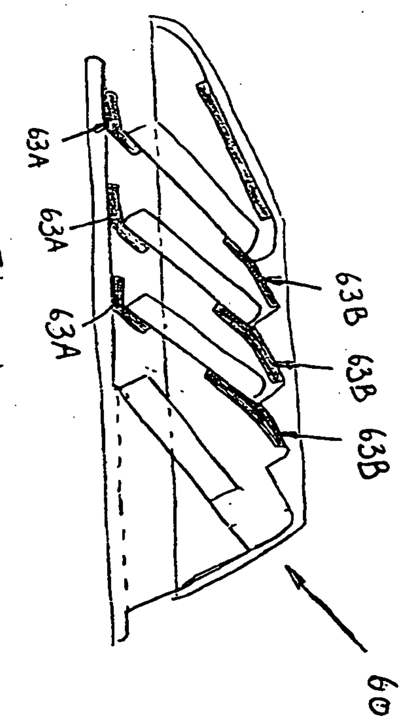


Fig. 6A

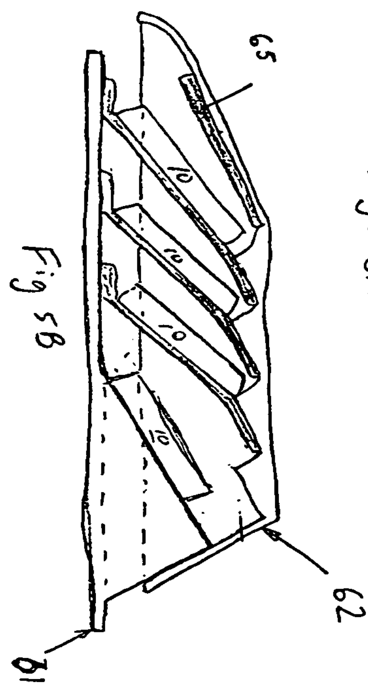


Fig 5B

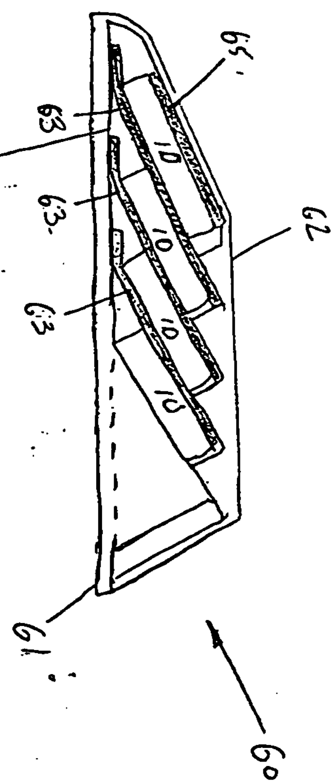


Fig. 5A

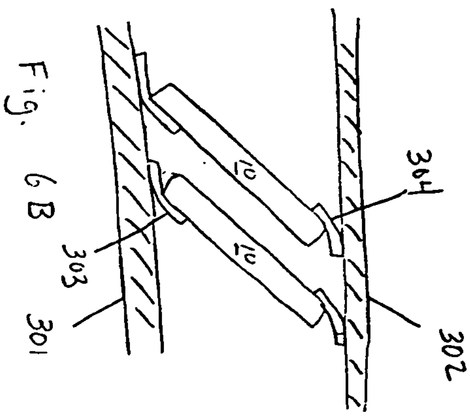


Fig. 6B

Fig. 6C

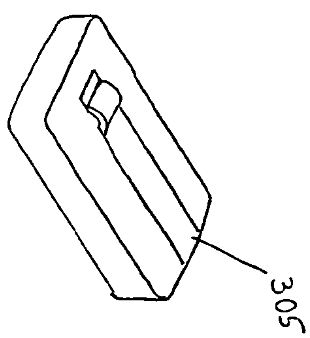


Fig 6D

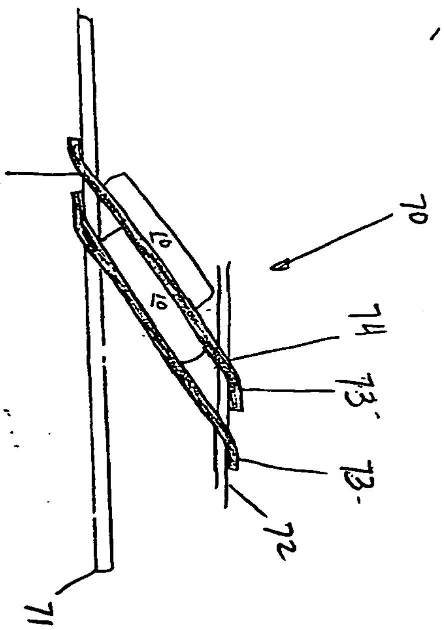
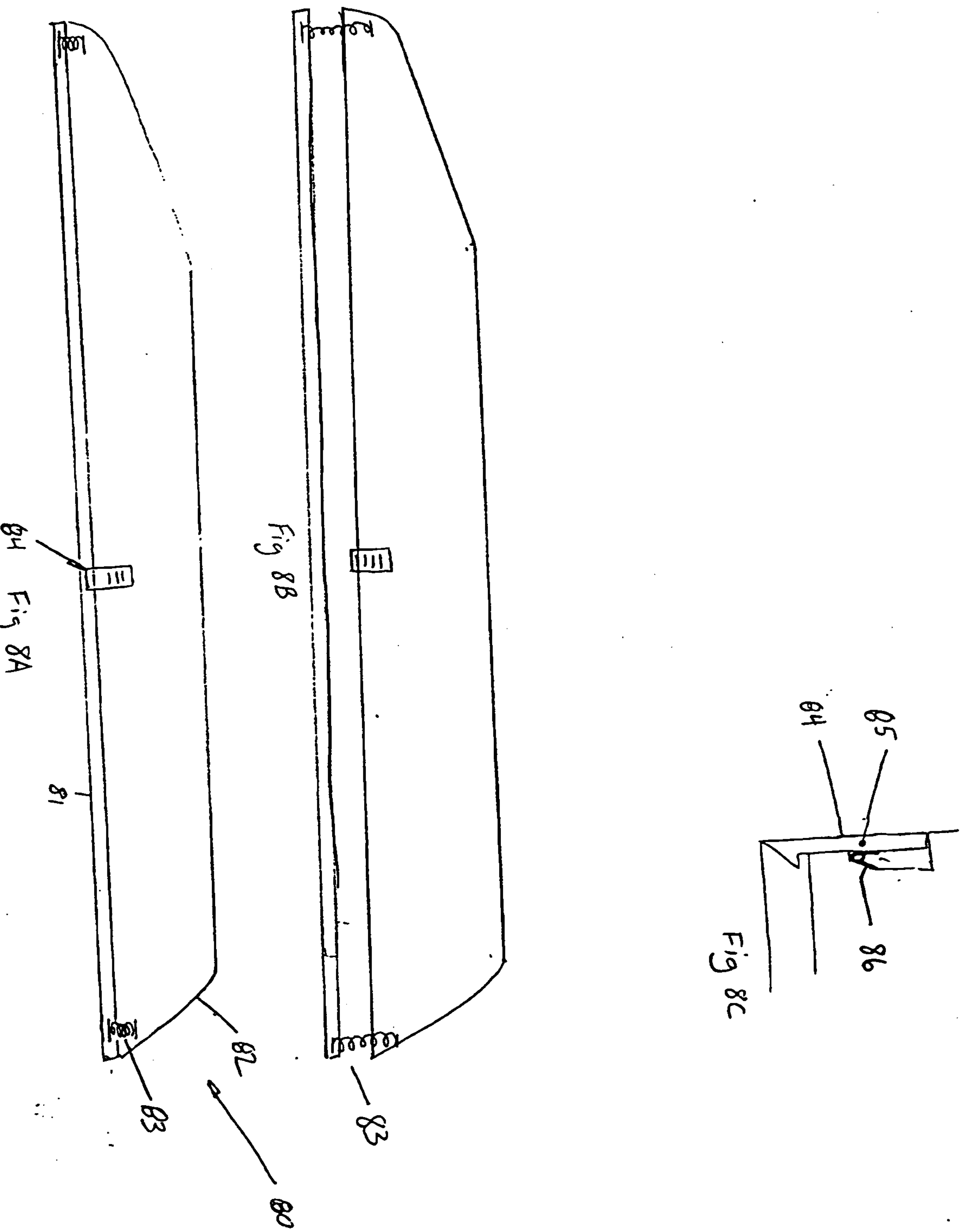


Fig 7


84
Fig 8A
81
82
83
80
Fig 8B
83
84
85
86
Fig 8C

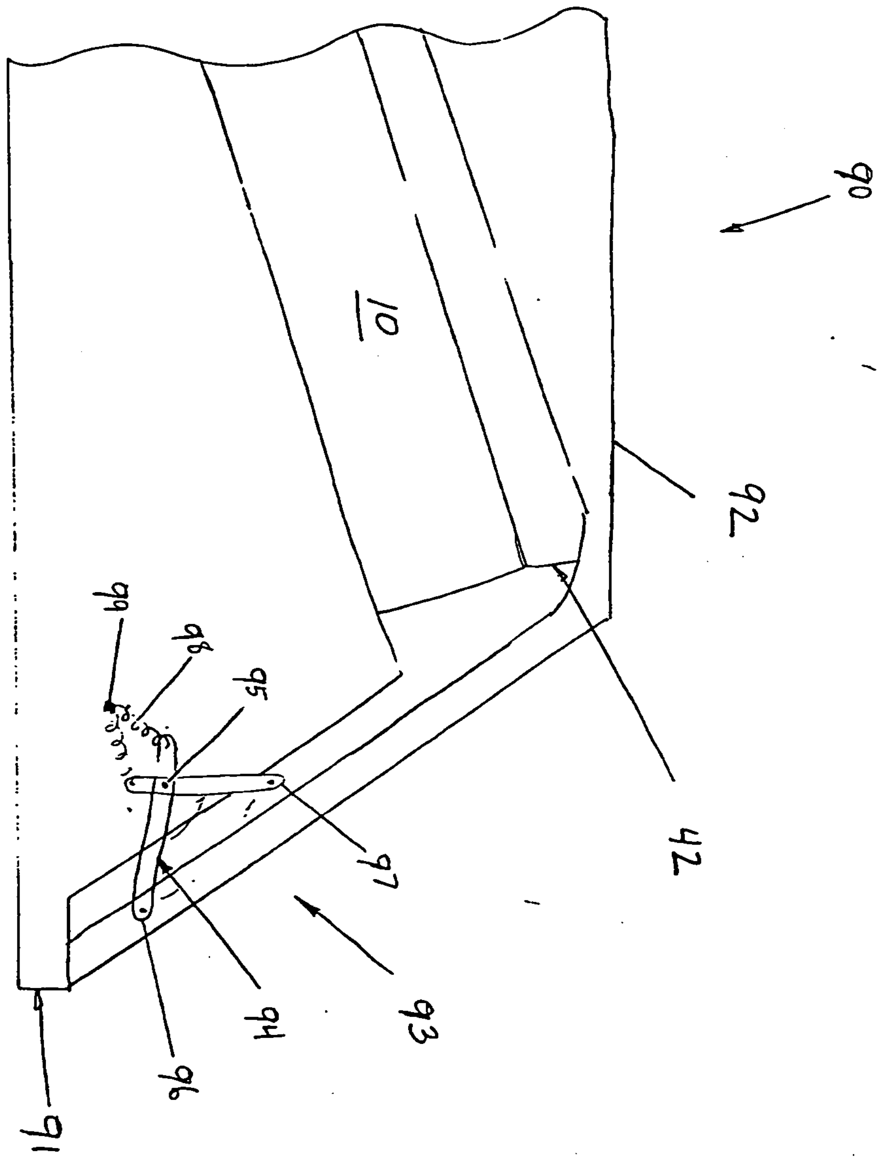


Fig. 9

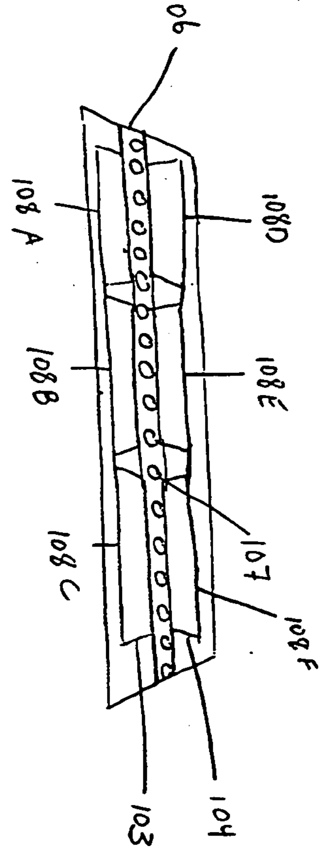


Fig 10 B

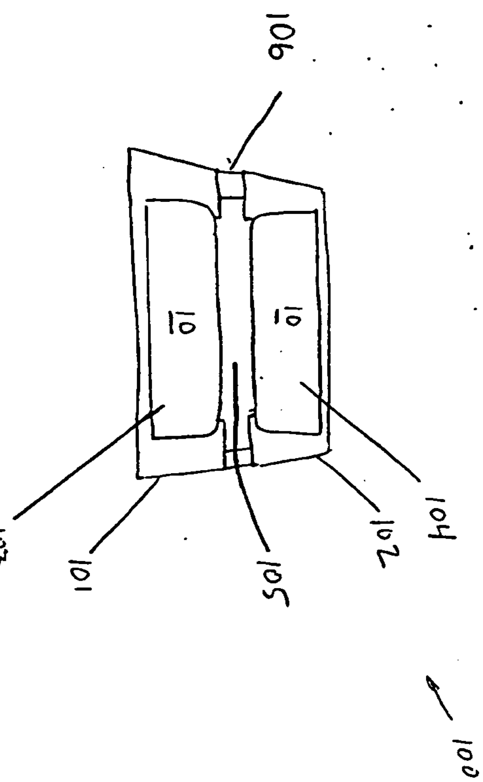


Fig 10 A

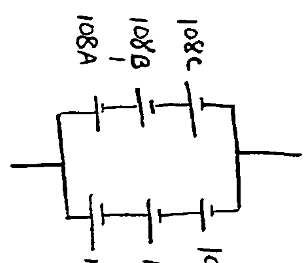


Fig 10C

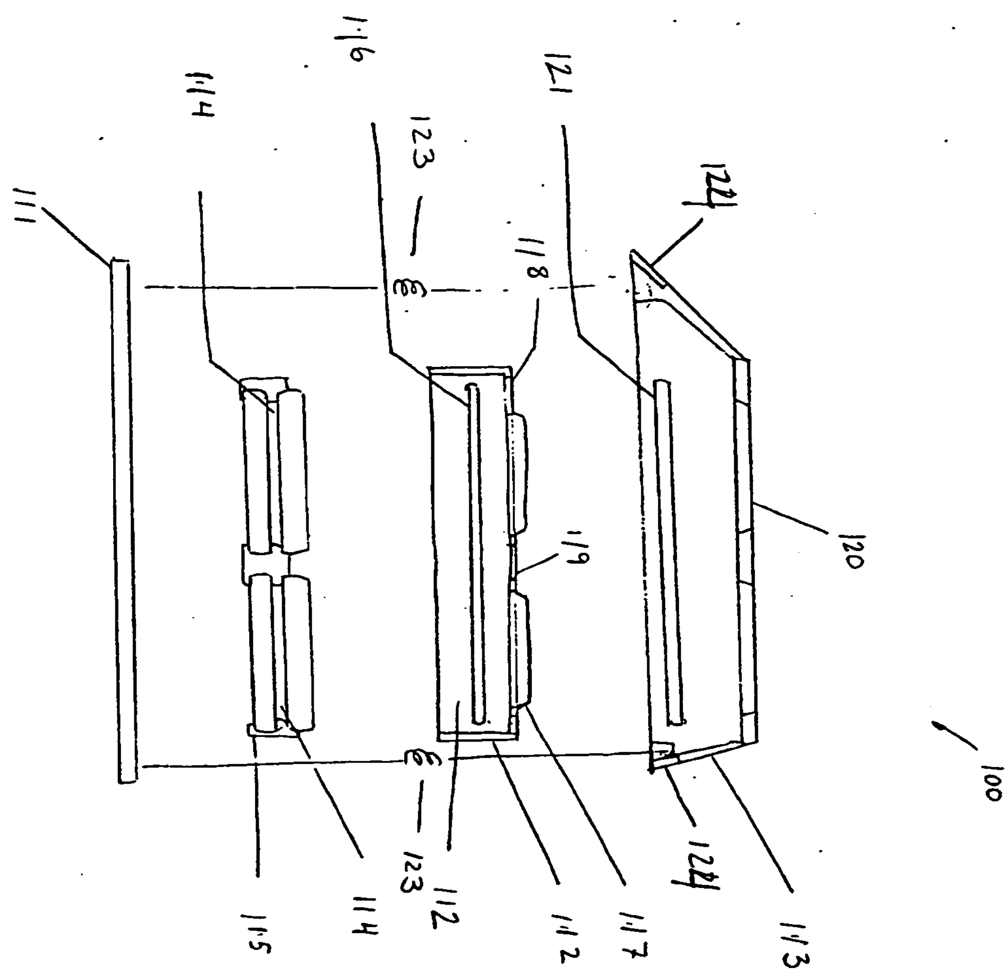


Fig. 11A

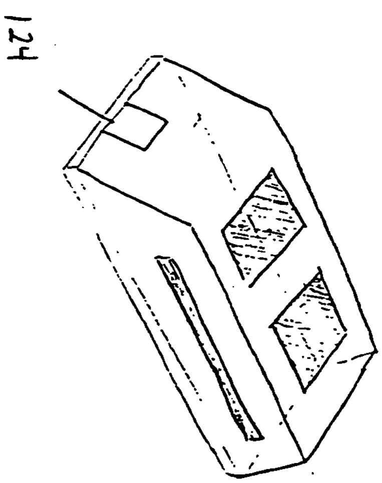


Fig 11B

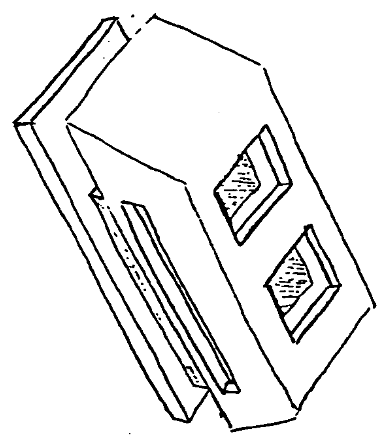


Fig 11C

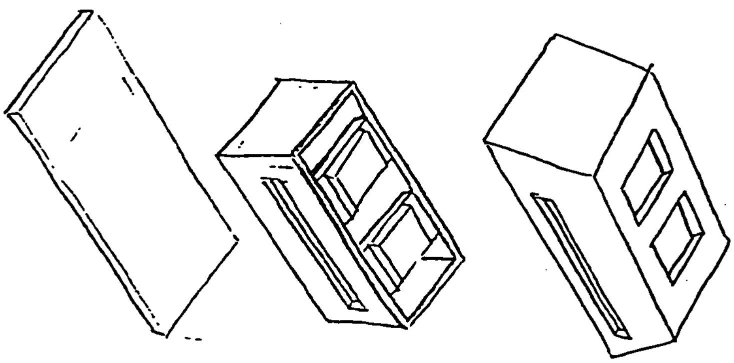


Fig. 11D

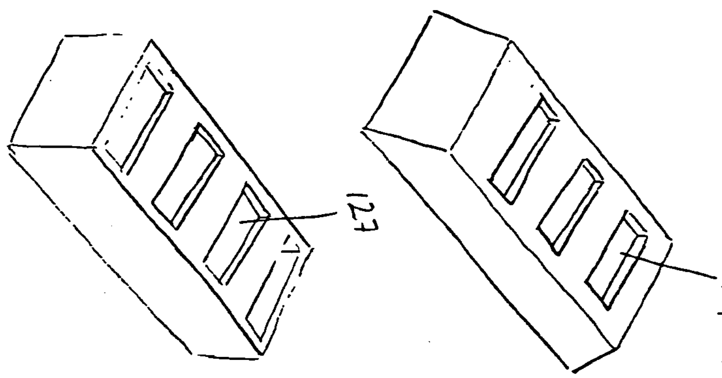


Fig 11E

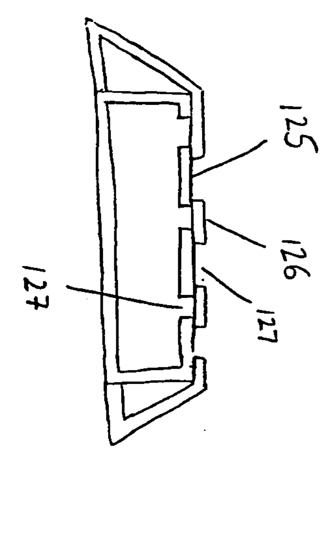


Fig 11F

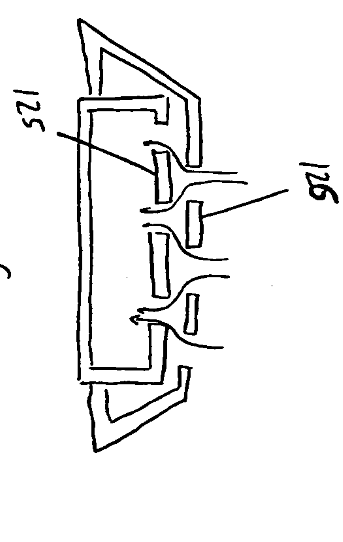


Fig 11G

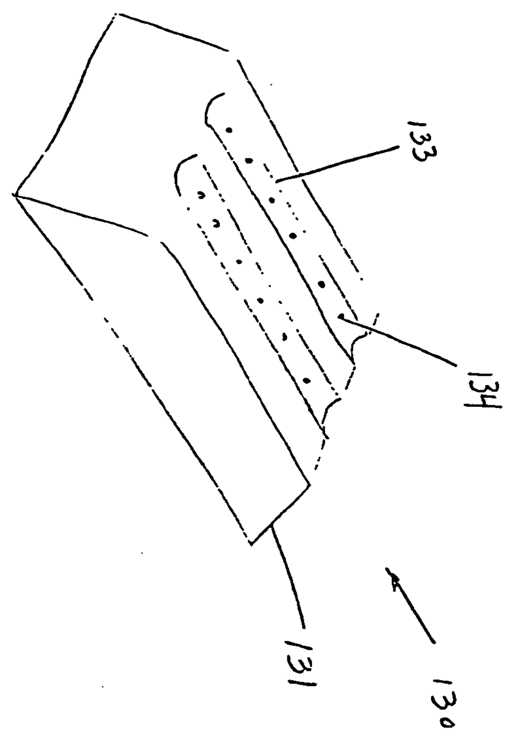


Fig 12 A

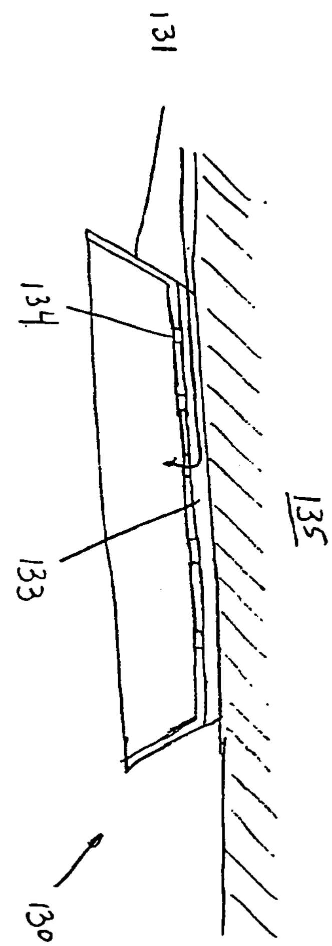


Fig 12B

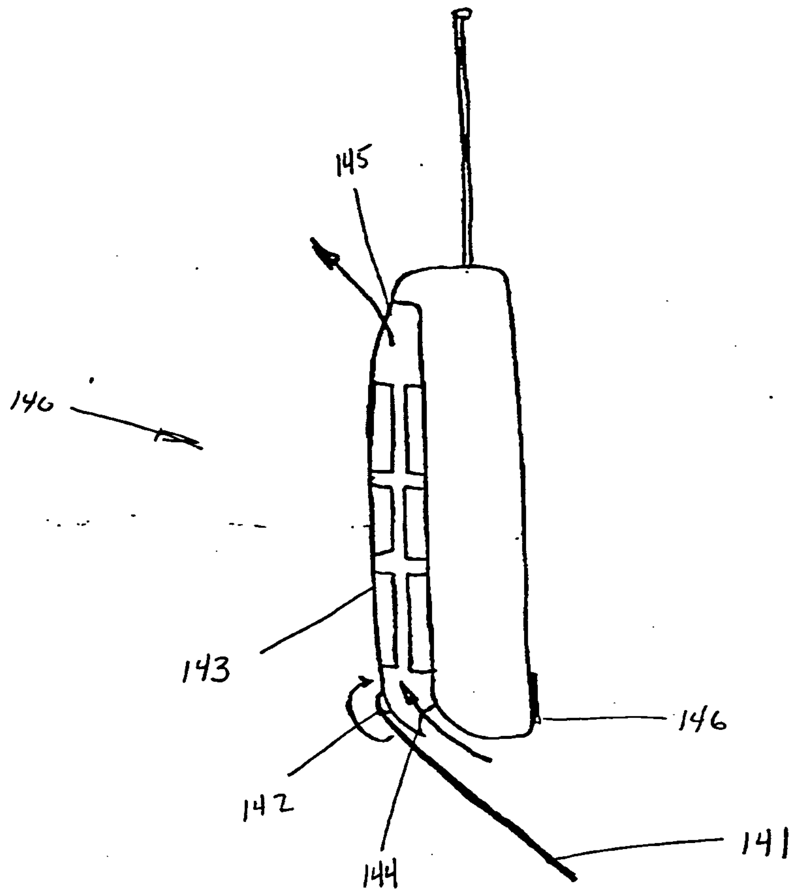


Fig 13.

FIGURE 14

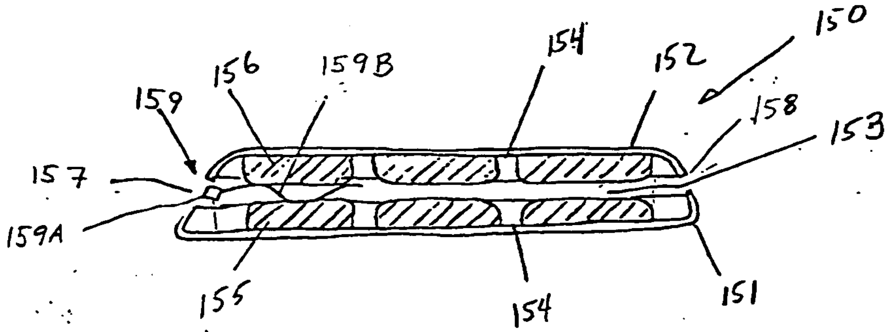


Fig. 14A

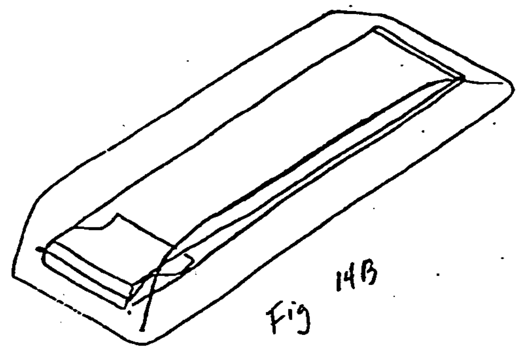


Fig 14B

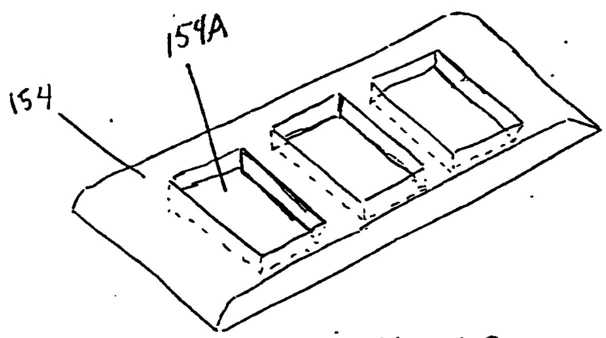


Fig 14C

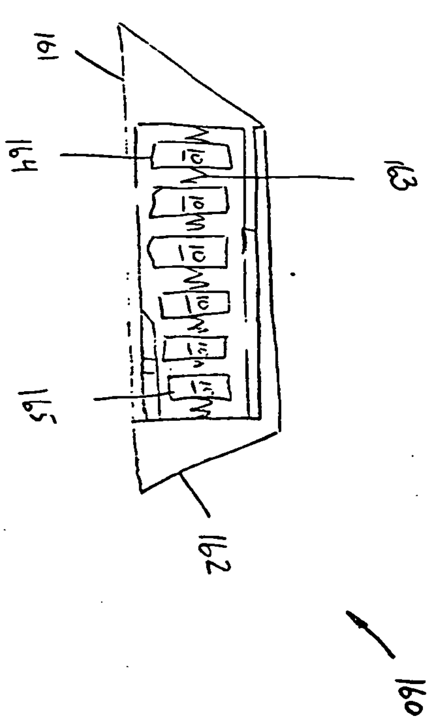


Fig 15A

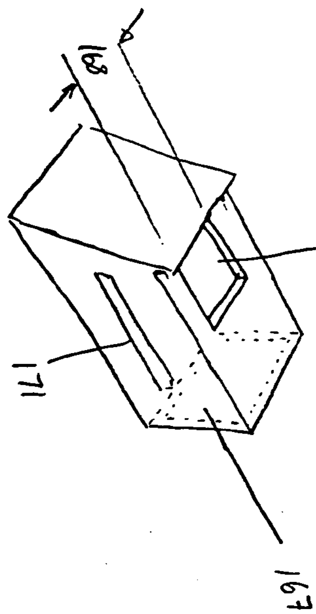


Fig 15B.

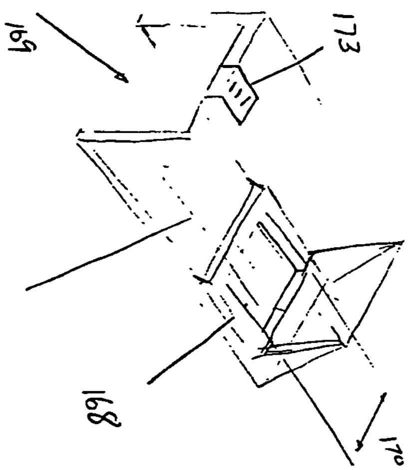


Fig 15C

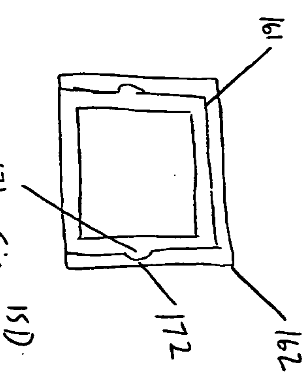


Fig 15D

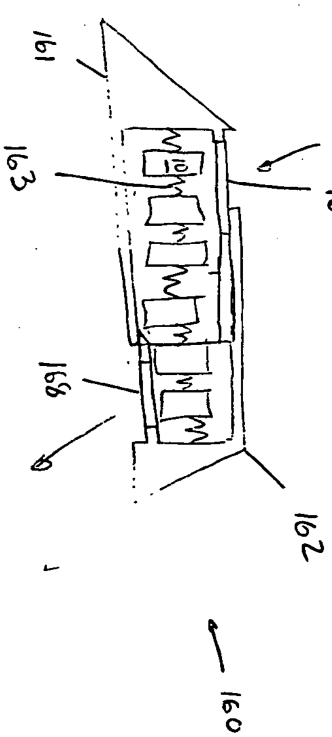


Fig 15E

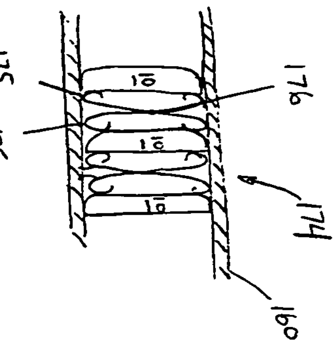


Fig 15F

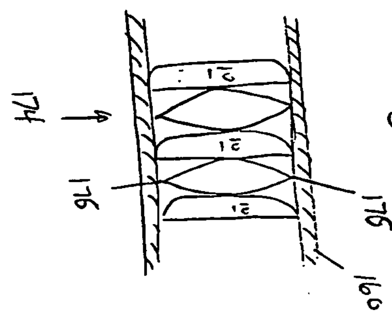


Fig 15G

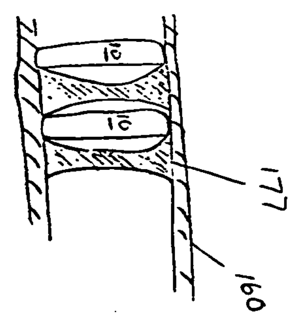


Fig 15H

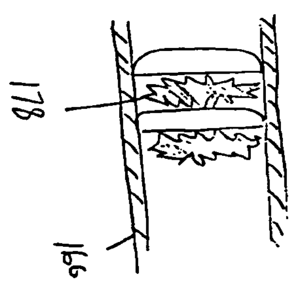


Fig 15 I

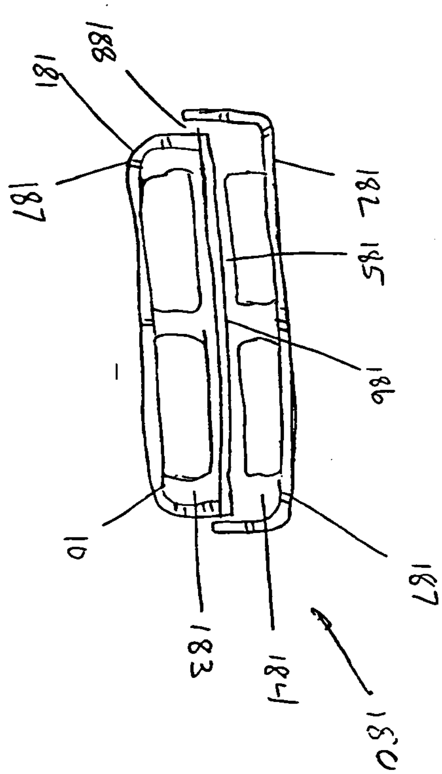


Fig. 16A

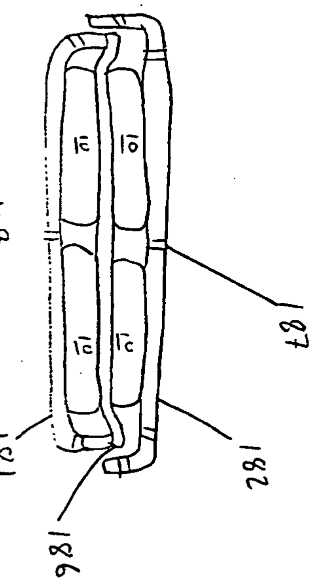


Fig 16B

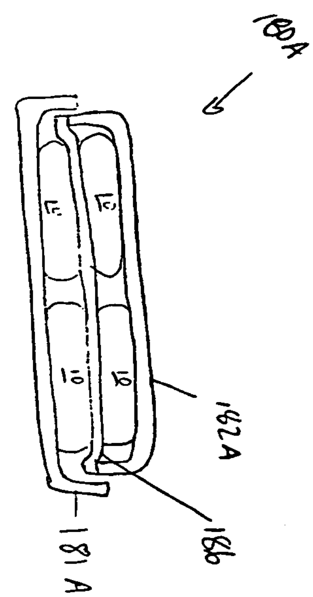


Fig 16C

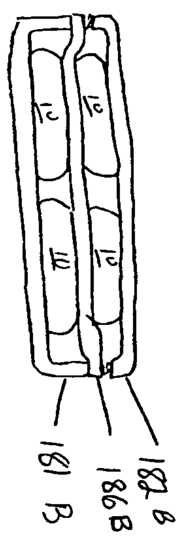


Fig 16D

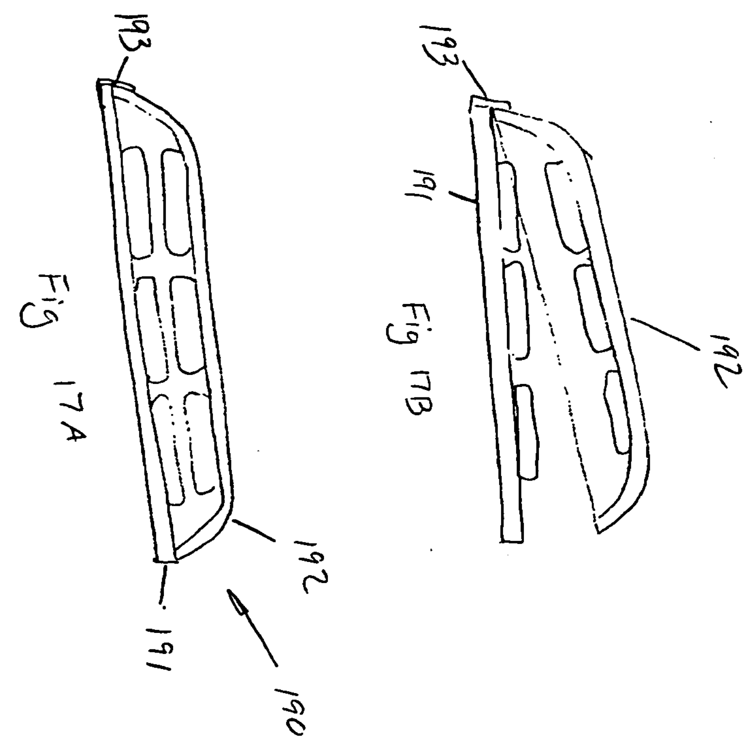


Fig 17A

Fig 17B

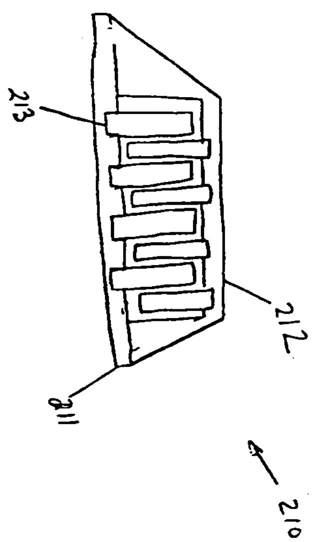


Fig 18A

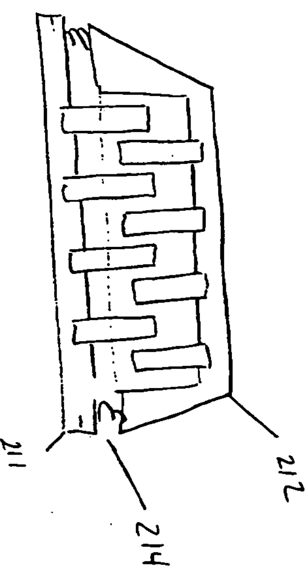


Fig 18B

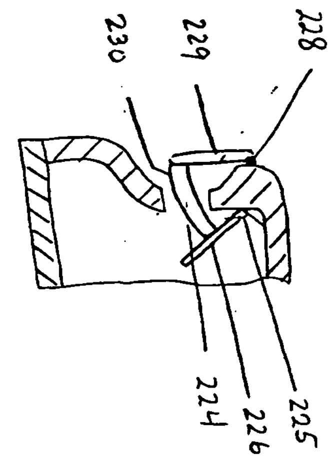


Fig 19C

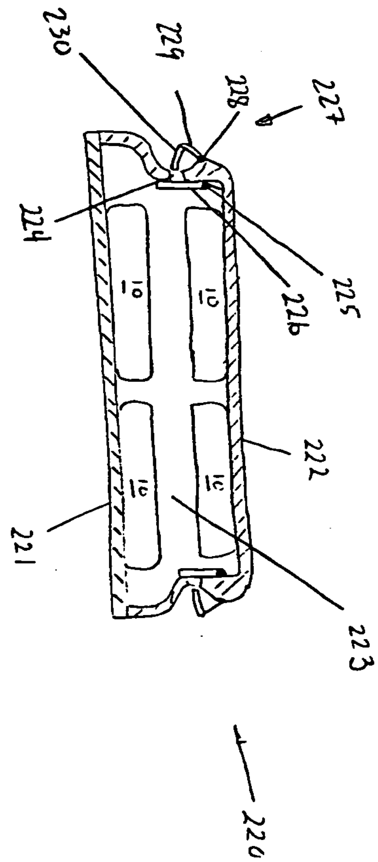


Fig 19A

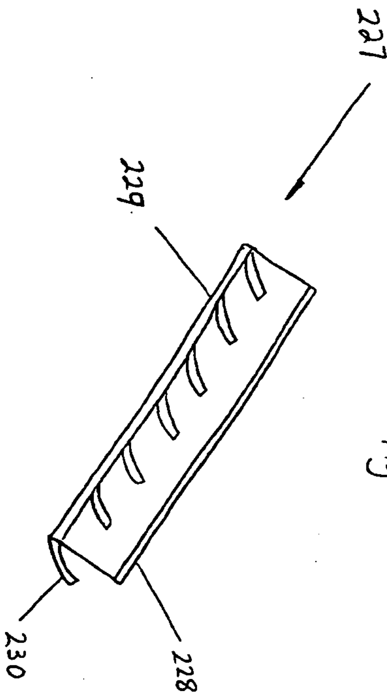


Fig 19B

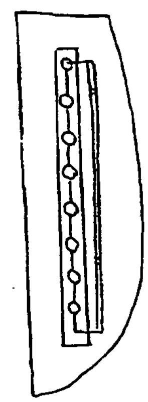


Fig 19D

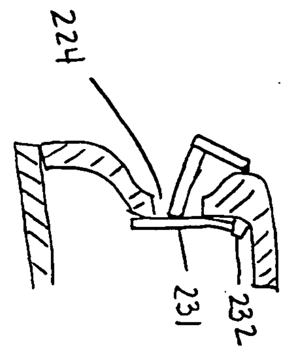


Fig. 19E

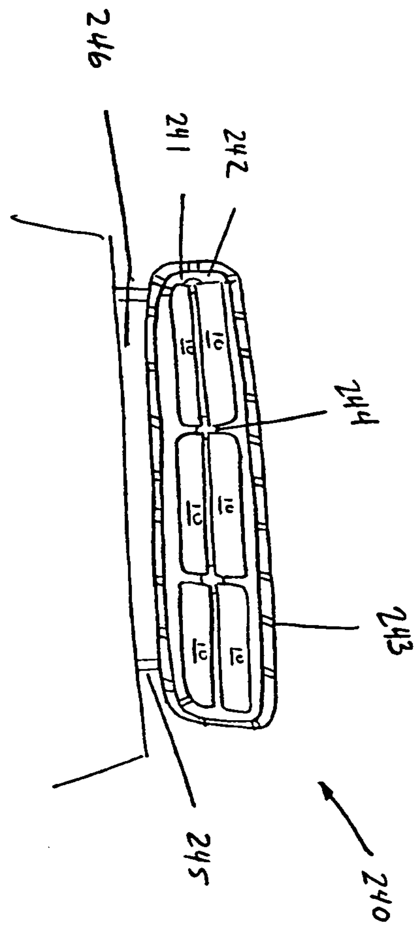


Fig 20

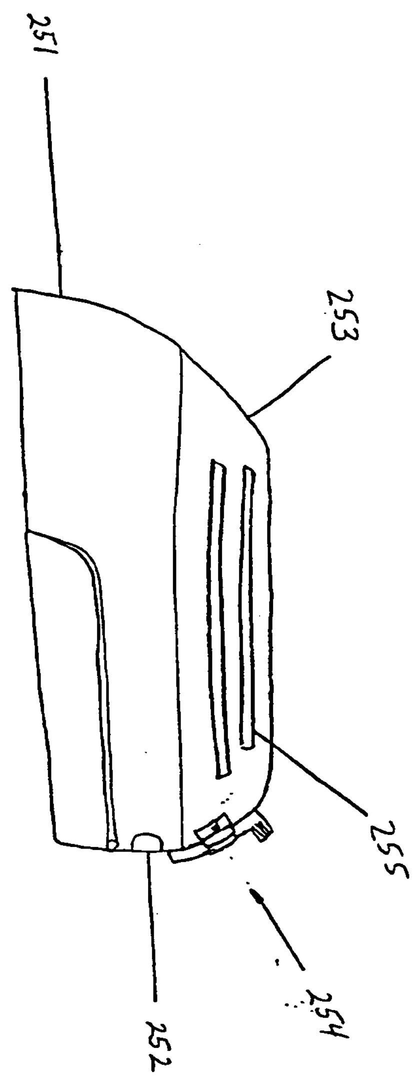


Fig 21A

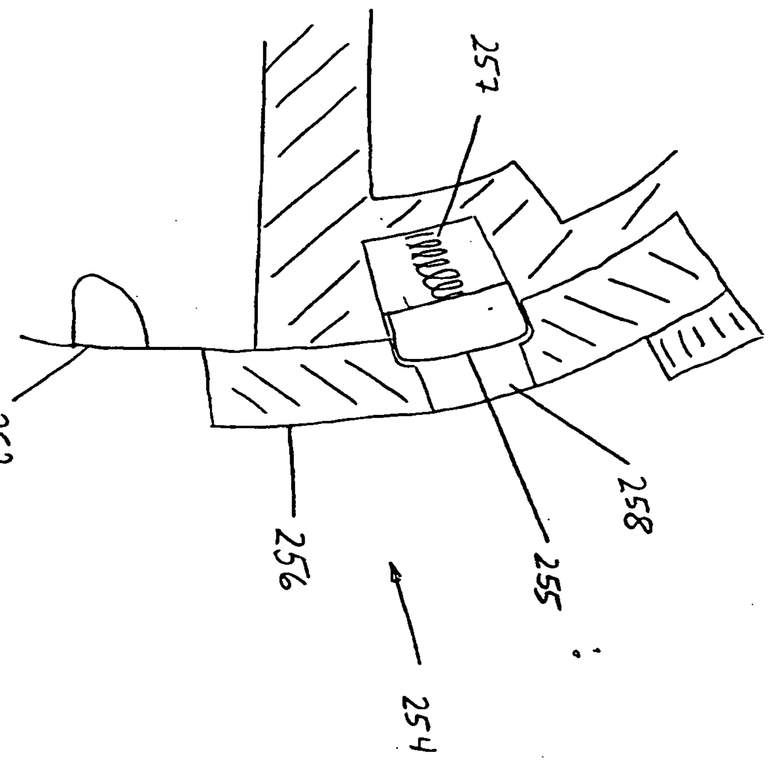


Fig 21 B

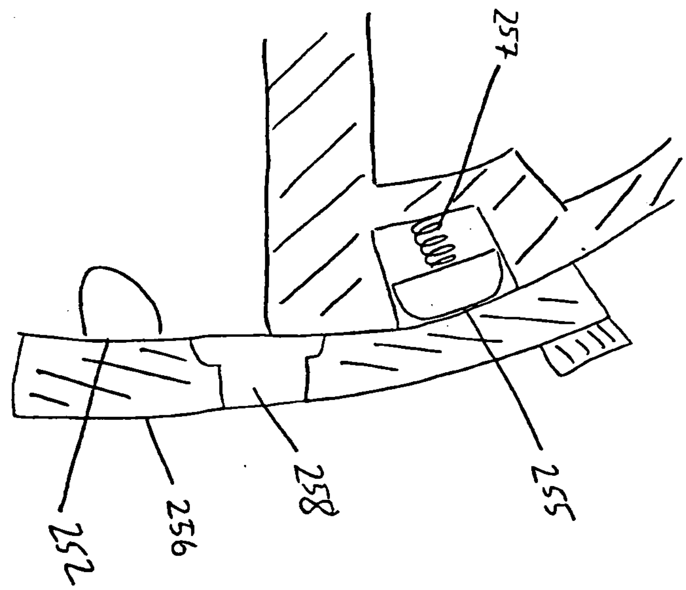


Fig 21C

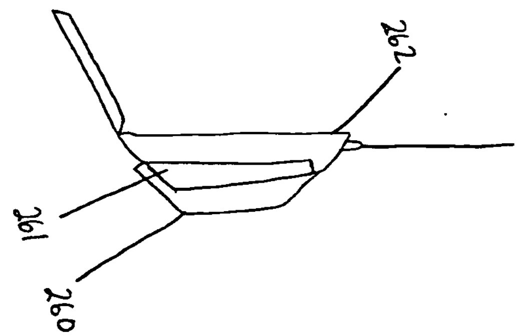


Fig 22

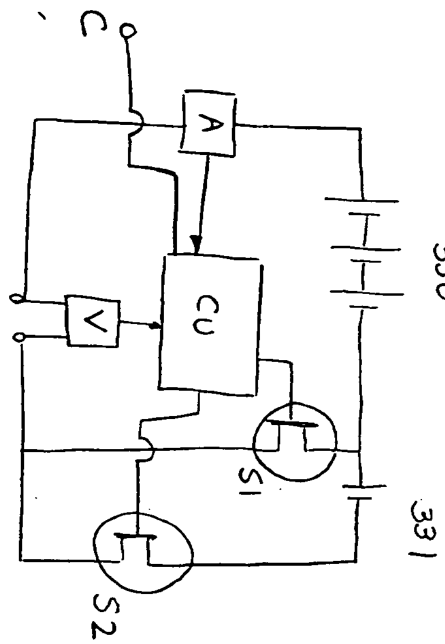


Fig. 23A

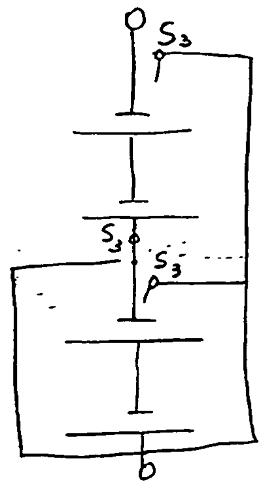


Fig 23C

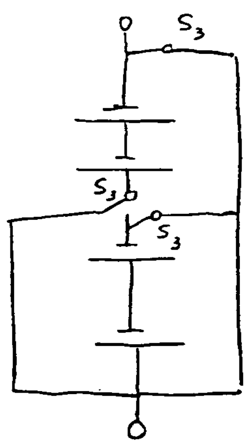


Fig. 23D

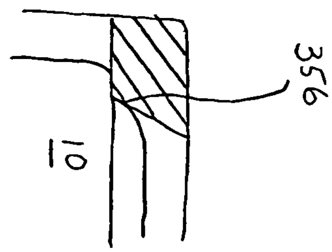


Fig. 24C

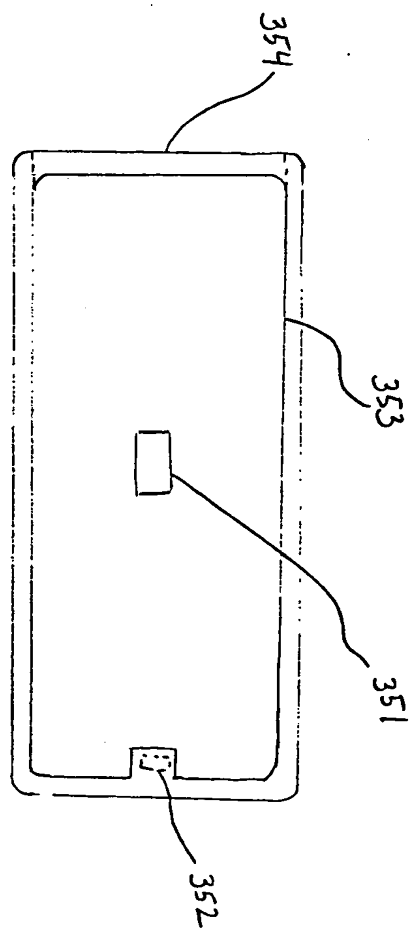


Fig. 24B.

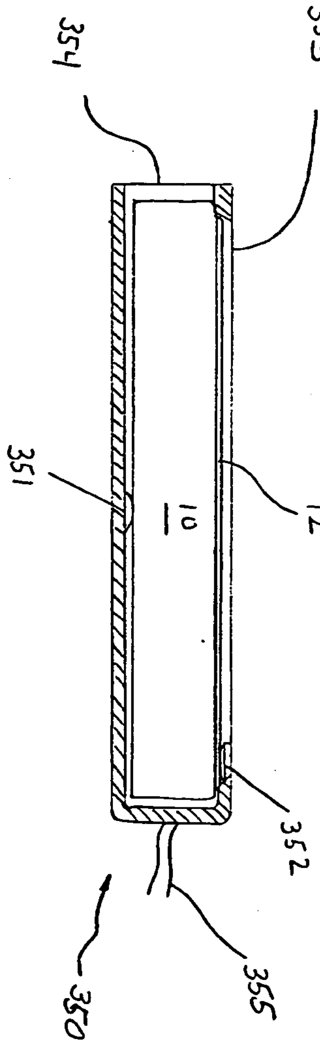
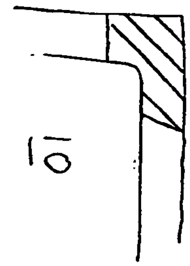


Fig 24A

Fig. 24D



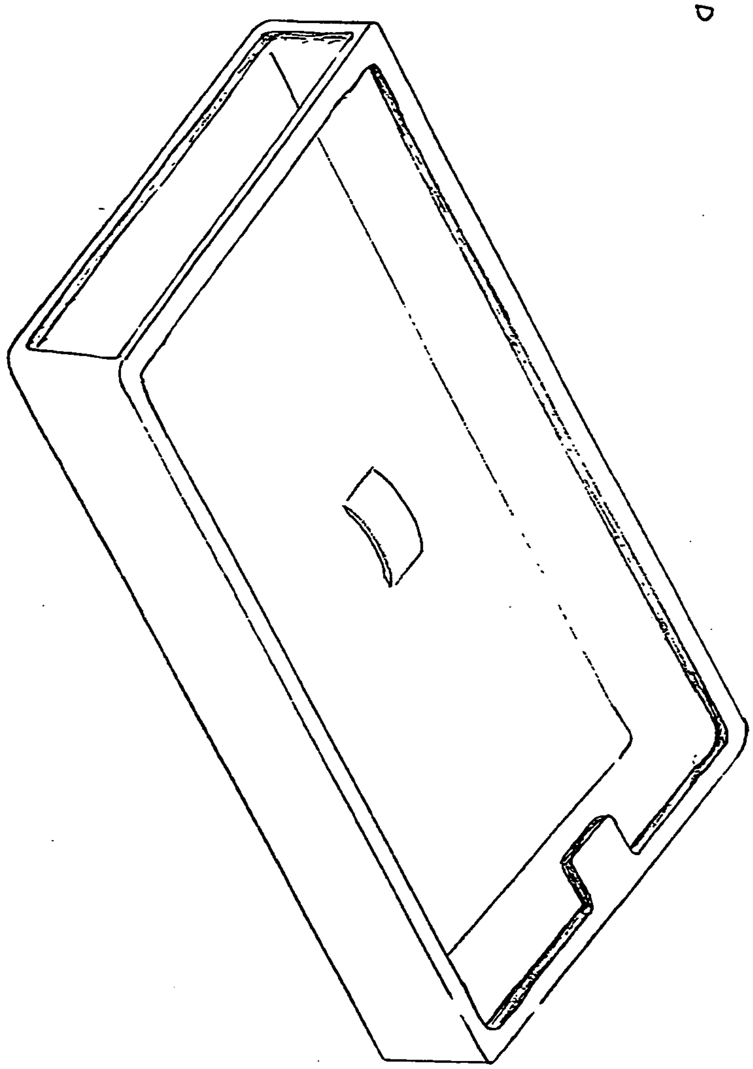


Fig 24E

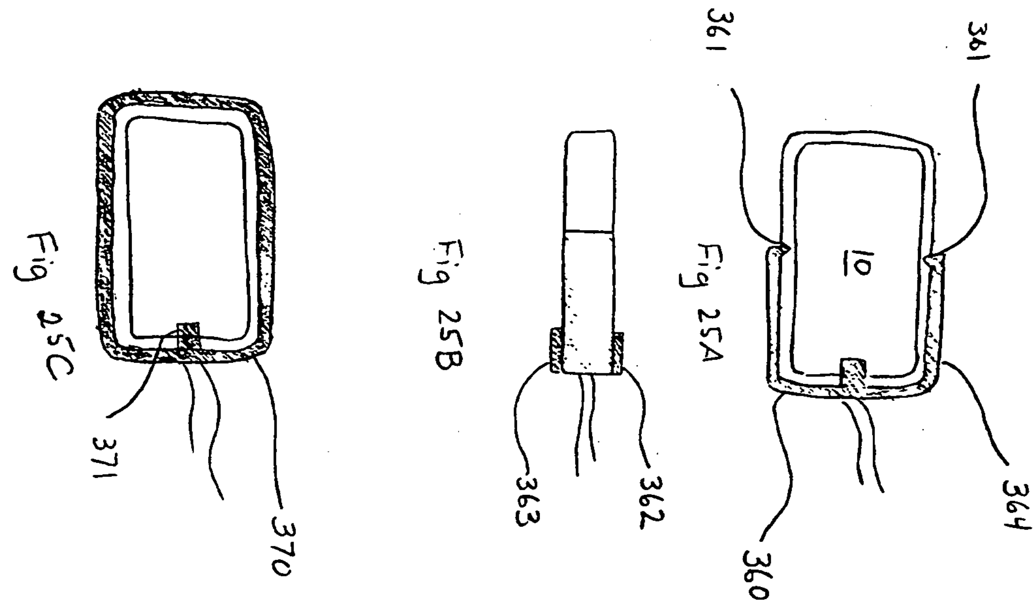

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Fig 25A
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363
Fig 25B
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Fig 25C